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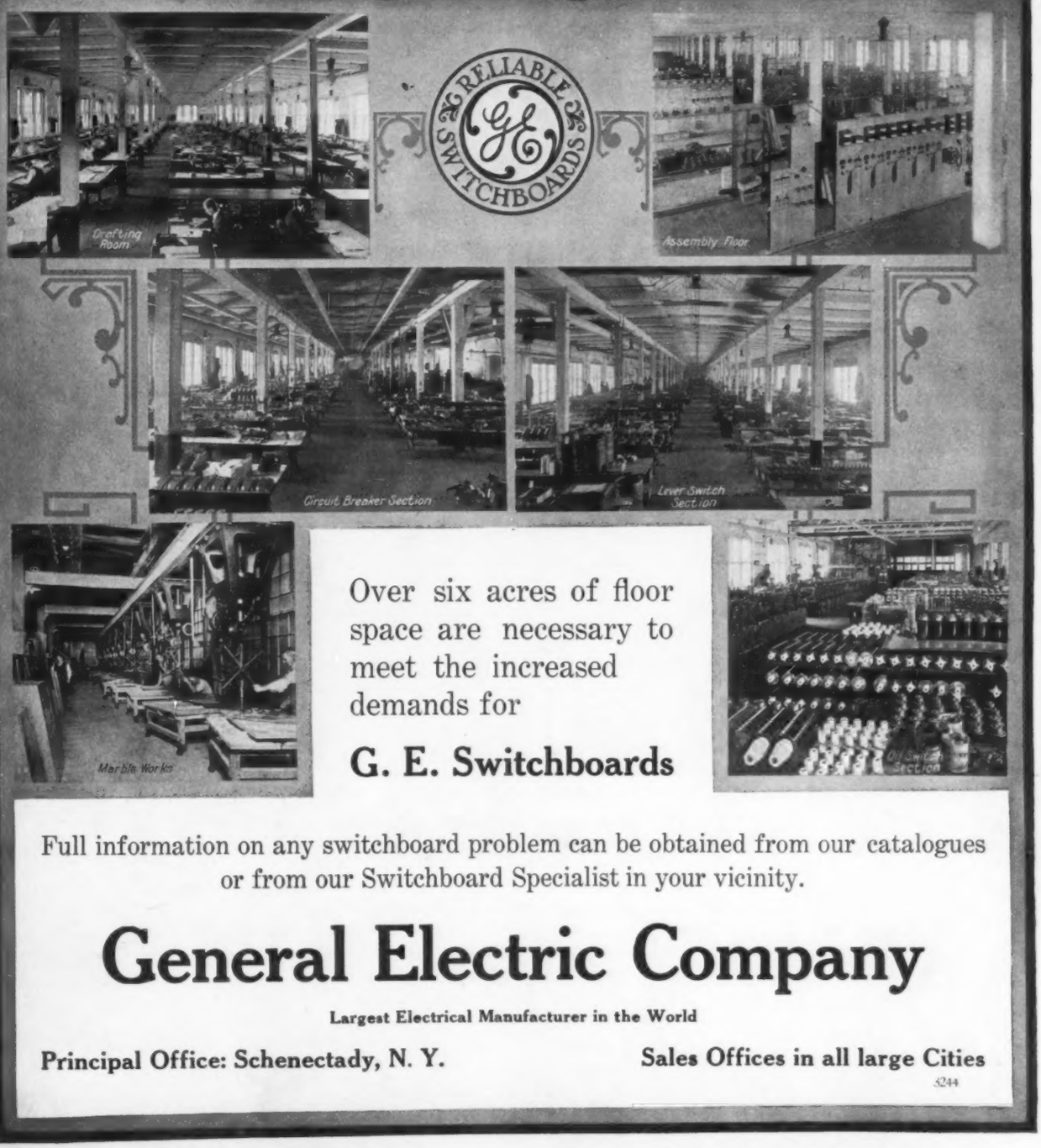

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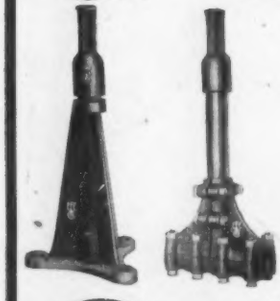

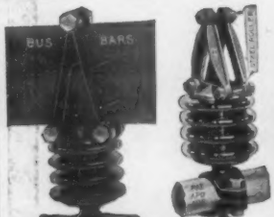

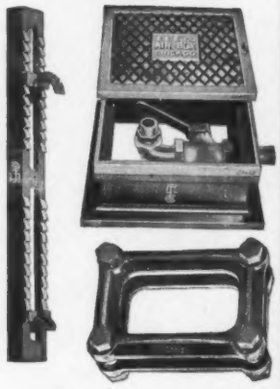

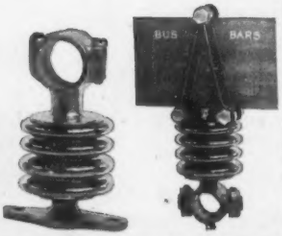

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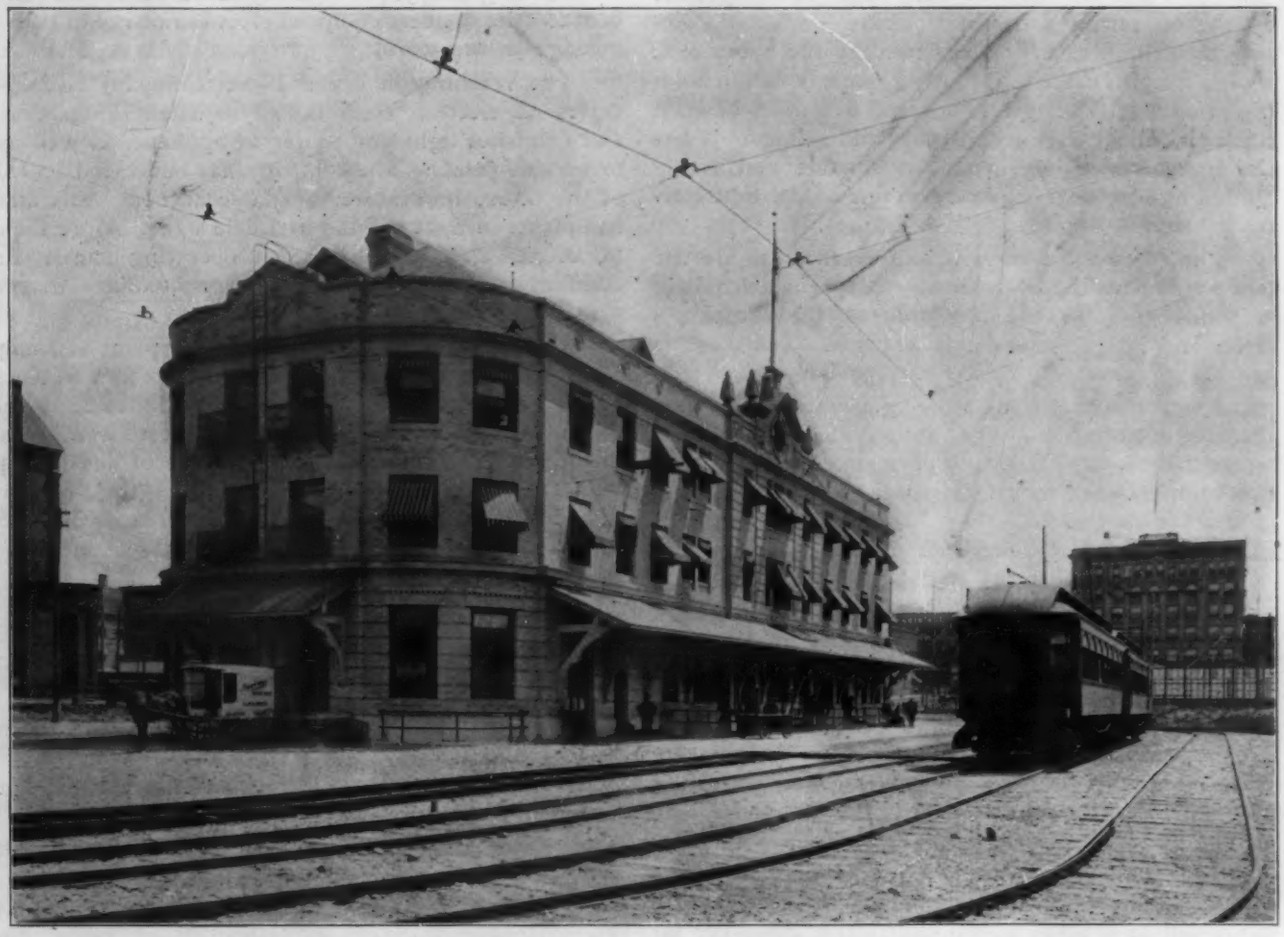
ELECTRICAL ACTIVITIES IN SPOKANE

Spokane has the third greatest system of interurban electric railways in America, being exceeded only by Indianapolis and Los Angeles. The city also has more miles of street car lines than any other city of similar population in the United States and Canada. The Washington Water Power Company and the Spokane Traction Company occupy 92.71 miles of streets and operate 154.11 miles of tracks, or nine-tenths of a mile of street occupied by tracks for every 1000 population. The total investment by the two companies is $42,000,000.



Spokane Terminal of Spokane & Inland Empire Railroad

Electric railway building in Spokane began in 1902. A. Bettis of Detroit, Mich., was the original promoter of the interurban electric road. He interested in his project F. A. Blackwell of Coeur d'Alene, Idaho, who, as the representative of the Howard Lumber Company of Pennsylvania, was attracted to the western country by the great timber reserves around Coeur d'Alene lake. Mr. Blackwell and his associates furnished the money, and, despite prophesies of financial disaster, the first interurban road from Spokane to Coeur d'Alene, 34 miles, was built. The road was opened

to traffic in the winter of 1903 and proved a dividend payer from the start.

Shortly before the completion of the Coeur d'Alene & Spokane Electric Road, Jay P. Graves, vice-president and general manager of the Granby Consolidated Mines & Smelting Company, entered into competition with the Washington Water Power Company for the street railway traffic of Spokane. Afterward he joined forces with Mr. Blackwell and the result was the organization of the Spokane & Inland Empire Railway Company with a capital stock of $30,000,000 and the construction of an interurban electric line, from Spokane south to Rosalia and Palouse, Wash. Later the Palouse branch was extended to Moscow, Idaho, and the Rosalia branch was carried to Colfax, Wash.

The Coeur d'Alene & Spokane Railway was absorbed by the Spokane & Inland Empire Electric Railway Company and the line was extended from Coeur d'Alene to Hayden lake, Idaho, 42 miles, and a spur of 17 miles built to Liberty lake, in the Spokane valley. Terminal facilities were acquired in Spokane by the organization of the Spokane Terminal Company, which, in turn, was absorbed by the Spokane & Inland Empire Electric Railway Company as the holding company. The system now has 175 miles of main track and about 60 miles of spurs and sidings. It has the most modern equipment obtainable and is regarded by electrical engineers as one of the best electrical roads in America.

The company also owns and operates an electric power plant on the Spokane river, from which power is transmitted for the operation of the company's street and interurban railway systems. The plant is capable of generating 20,000 horsepower.

Spokane's interurban railway facilities were further extended by the Washington Water Power Company, then a $20,000,000 corporation, constructing a line from Spokane west to Medical lake, 18 miles, and later a branch line to Cheney, 11 miles, making a total of 250 miles of interurban electric road.

Foremost among the electric railway projects in the Pacific States is the Spokane & Inland Empire system, operating 235 miles of main lines and branches in eastern Washington and northern Idaho. When completed this system, now controlled by stockholders of the Great Northern Railway Company, will have extended its tracks into territory not now reached by either steam or electrical lines, as well as not being accessible to tidewater and the Columbia and Snake rivers.

The company operates a power plant at Nine Mile bridge, where the waters of the Spokane river are harnessed to develop 12,000 electrical horsepower for operating railway lines and furnishing light and power. The development of this energy was accomplished by diverting the river from its natural channel, in itself an engineering feat of high order.

The dam is 70 feet thick at its base and 225 feet in length, exclusive of the power house, which is 110 feet wide by 85 feet by 87 feet above low water mark. The river has an estimated average flow of 12,000 cubic second feet. The dam creates a head of water of 60 feet, also backing the river five miles, thus furnishing a storage which will carry large fluctuations of load. The plant will accommodate four 5,000 horsepower units, two of which have been installed. The generators are 3750 kw. three-phase, 2200 volt; 60 cycle alternators. The company also owns a power site just outside the city limits of Spokane, which may be developed in the future.

On the lines now in operation the single-phase system is employed. This is the first of its kind to be operated in the Northwest and it is a success in every way. How it is viewed by electrical experts is probably best summed up in a statement by Geheimrath Wittfield, heading a royal commission of Germany appointed by Emperor Wilhelm, who said, after inspecting the lines and power plants in Spokane, that what he and his associates had seen had more than repaid them for coming across the seas and continent, adding:

"Taking altogether the Spokane & Inland undoubtedly is the best equipped electric railway of equal mileage in the world."

The Washington Water Power Company also operates an electric street railway system in Spokane and furnishes light and power in Spokane, as well as to various points. The company has developed 16,000 of the 60,000 horsepower available at Post Falls and has plants in Spokane and at Little Falls. More than $17,000,000 already is invested in operating plants. In addition it has a 5000 horsepower auxiliary steam plant in Spokane.

The company is installing a power plant at Long Lake, 23 miles north of Spokane, where about $4,000,000 is being invested. The project includes 23 miles of standard gauge steam road, the highest "weir" dam in the world and four turbines, capable of developing 90,000 electrical horsepower, or equalling the capacity of five water wheels at Niagara Falls. The dam is 300 feet in length, 175 feet in height and 150 feet in thickness at the base.

NOVEMBER MEETING LOS ANGELES SECTION A. I. E. E.

The Los Angeles Section of the American Institute of Electrical Engineers will meet on November 21, 1911, when Professor Harris J. Ryan will present a paper on "Polarity in Alternating Current Circuits." At the same time Professor W. A. Hillebrand will present a paper on "Some Fundamental Considerations in the Applications of a System of Graphics to Alternating Current Circuits," this paper constituting an introductory discussion to that of Professor Ryan. Visiting engineers who may be in Los Angeles at this time are cordially invited to be present and to participate in the discussion. In order that those desiring to so participate may be amply prepared in advance these two papers are printed in full in the following pages.

POLARITY IN POLYPHASE CURRENT CIRCUITS.

BY HARRIS J. RYAN.[1]

Introduction.

In 1890 through the efforts of C. E. L. Brown and others the three-phase induction motor and system of electrical power transmission and distribution were developed and introduced in Europe. Simultaneously and quite independently in the United States Tesla and others developed and introduced the corresponding two-phase induction motor and system. The two-phase system promptly encountered in our country the competition of the three-phase system imported by the rivals of the interests in control of the Tesla patents. At the time the expected development of these two systems under an intense commercial rivalry was not a very pleasant thing to contemplate. It was supposed that the machinery and appliances of the one system could not be employed in the other. To cover the business of the country with both systems would mean a duplication of plant and of fixed charges that from the beginning would be too severe a burden for the consumers of electric power to support. As a consequence during the three years that followed, 1891-4, electrical engineers formed two groups, evenly matched in technical and industrial strength and decidedly hostile in regard to these fundamental methods. One advocated the universal adoption of the two-phase and the other the three-phase system for general purposes. Then an extraordinary thing happened. Mr. Chas. F. Scott announced in a paper before the National Electric Light Association his method for transforming from a two-phase to a three-phase circuit, and vice versa. The effect upon the strenuous controversy was marvelous. It was dropped almost in a day.

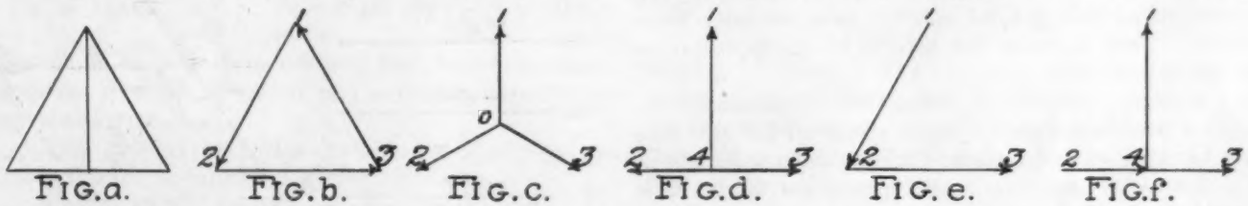


Fig.a. Fig.b. Fig.c. Fig.d. Fig.e. Fig.f.

This was the first result of the study of polarity in polyphase current circuits. One dare say that brilliant as was Mr. Scott's achievement, for he stopped the great battle of the phases, the mental effort he put into it was as a mere trifle compared with the enormous energy that had already been expended in the conflict between the rival camps in their attempt to establish the supremacy of the one system over the other, and with little or no result of positive value. This great victory for the electrical industries was, however, accepted largely as an isolated case, with little conscious realization at the time of the breadth and depth of the underlying principle it involved. To express the relation between the phases, circuits and voltages in his two-phase: three-phase system of transformation Mr. Scott used the familiar T-delta diagram of Fig. a. While the lines in this figure are alternating quantities and therefore vectors, the usual vector arrow heads had to be frankly omitted to avoid manifest conflict in the ideas to be conveyed. It is now seventeen years since this discovery of Mr. Scott was made. To this day for the most part polyphase circuit diagrams of the Fig. a. class are made up of connected lines with their arrow heads omitted; a frank admission that the diagram is incomplete. For example it is well known that the three-phase sources produced at the terminals 1, 2 and 3, by the polyphase current circuits designated in Figs. b, c, d, e, and f, are identical. It required years of trial and effort before we realized our present knowledge of these and similar polyphase circuits. Even now it is a most perplexing matter to those who are not thoroughly at home in this subject to realize that the terminals 1 and 2 in the polyphase circuits Fig. d and Fig. f are sources of voltages, identical in amount and phase positions. This again is due to the fact that while these diagrams are true and correct so far as they go they do not include a designation of all of the essentials that constitute the polyphase circuit because they have omitted the circuit polarities.

The general use of direct current began with the development and manufacture of the Gramme dynamo in 1872. There were alternators before that, of a sort, but men did not know how to use alternating currents except to a discouragingly small extent. During the fifteen years, 1872 to 1887, an immense amount of knowledge and experience in direct current working accumulated. In that experience polarity of e.m.f.'s currents and circuits was most everything of importance. Transmission to greater distances forced the development of the transformer from the old Rumkorff induction coil and the introduction of the single-phase system for incandescent lighting in 1885. The demand for a self-starting alternating current motor forced the development of the induction motor from the beautiful rotation experiment of Ferraris, resulting in the practical introduction of the polyphase systems about 1890. There were thus about five years of straight single-phase practice in which the habit developed of neglecting as much as possible polarity in alternating current circuits. The whole nature of things in alternating current working has contributed greatly to deaden the polarity sense, so fully and keenly developed in the direct-current working that preceded the development of the alternating current methods.

The object of the present paper is to contribute toward a development of the polarity sense applied to modern alternating current practice. The polarity sense should not have been neglected during the early introduction of alternating currents. Technical progress would have been made with less expenditure of energy. Our present mental attitude in these matters would be more satisfactory with a stronger development of the relations of polyphase circuit polari-

[1]Professor of Electrical Engineering, Leland Stanford University.

ties. Primarily the effort herein has been to assist those who are now taking up polyphase currents for the first time. The paper was therefore written much in the form of a text and amplified somewhat as such. No effort was made to lessen the task for those who do not care to go so fully into the subject. It is realized, however, that there are many who would like to understand something of the subject and to know to what extent it will pay them to make a study of it. With these facts in mind Professor Hillebrand kindly consented to discuss the paper. The author advises all who are interested in the subject to read Professor Hillebrand's accompanying discussion first and then to take up the text of the paper according to their inclination and needs.

Vector-Circuits:

In the graphic treatment of polyphase currents and their circuits, vectors have to do double duty,—they must express the alternating values and designate their corresponding circuits properly connected. Thus employed they may be called **Vector-Circuits.** Without proper system, irrational use of vector-circuits is easily made and corresponding confusion results. Polyphase current problems in modern practice and the needs of corresponding good teaching now demand a rational and systematic use of the vector-circuit. Some excellent contributions to the literature of this general subject have recently been made.[1] They indicate the arrival of an appreciation of the subject.

It is the purpose of the author to present herewith a text based on a system of vector-circuits that has been developed by him during the past decade in his work of instruction in polyphase currents. It is hoped that all who are prepared to contribute to the subject will do so. This, it is hoped, will lead to the common consent adoption of some one convenient, **rational and standardized system of graphics for the treatment of polyphase currents and their circuits.**

Conventions.

A vector employed to designate an alternating quantity and its circuit is a vector-circuit. In a vector-circuit the vector-length and direction designate the amount and phase of the alternating quantity, while the vector-line with its ends designates the corresponding circuit with its terminals.

A small circle attached near one end of the vector and the usual arrow head indicate that the vector is a vector-circuit, made up of an alternating quantity and its corresponding circuit; the vector-circuit end, toward which the small circle is attached, is the positive terminal of the circuit, and the arrow-headed end determines the positive direction of the vector. See Fig. 1.

A positive direction through a circuit is from the negative to the positive terminal of such circuit.

A positive direction in any closed circuit is taken anti-clockwise.

A vector-circuit is closed "direct" when a positive direction through the closed circuit leads in a positive direction through its corresponding vector-circuit.

Illustrations of the foregoing definitions:

[1]Notation of Polyphase Circuits, by Charles H. Porter; The Electric Journal, Sept., 1907.

A vector-circuit has four signs: a plus and minus sign, **each,** for the alternating quantity and for the direction in which the circuit is connected.

When letters are used as symbols to designate vector-circuits the first sign of the letter is the sign of the alternating quantity, while the second sign of such symbol is the sign of the corresponding circuit. The reversal of a vector-circuit effects, therefore, no change in the practical effect because in such reversal both an alternating quantity and its circuit have been reversed, a process that always leaves the effect unchanged. From this it follows that a **vector-circuit is the exact working equivalent of its equal and opposite vector-circuit.** In the graphic treatment of a community of vector-circuits the working result is not affected by reversing one or all of them.

In Fig. 1, $+e+$ and $-e-$ or $+e-$ and $-e+$ are **similar** vector-results, while $+e+$ and $+e-$ or $-e+$ and $+e+$ are non-similar vector-circuits. Vector-circuits are similar when their vectors and corresponding circuits have the same terminal relation, viz., the positive ends of all such vectors and circuits coincide or are opposed; they are non-similar when they do not agree in their terminal relation.

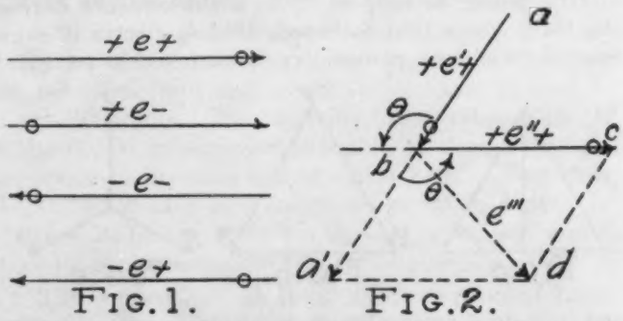


FIG. 1.

FIG. 2.

Triangulation is a convenient operation to determine results produced by given vector-circuits: operations upon double-vectors by parallelograms and their diagonals are not convenient because the resultant alternating quantities and their corresponding circuits are not coincident as is the case in triangulation.

Triangulation is illustrated in the following example:

In Fig. 2. two e.m.f.'s having a phase difference of θ degrees are written in the usual **vector-chain** fashion, wherein the end of the last vector becomes the origin from which to mount the next vector for a series of e.m.f.'s, In such cases the exterior angle formed at the junction of a pair of vectors is the measure of their phase difference.. The small circles toward the positive ends of these vectors indicate that they are likewise the corresponding containing circuits, thereby constituting them vector-circuits. There is represented in this figure the practical case of an open-delta, three-phase e.m.f. source. What e.m.f. will be delivered between the terminals **a** and **c**? When a loading circuit connects across **ac,** each of the circuits **ab** and **bc** containing the e.m.f.'s **e'** and **e"**, is connected into the circuit **abca** thus formed, in a positive direction. **Evidently,** then, the resultant e.m.f. in the circuit **abc,** applied between the terminals **ac,** will be the vector sum of the e.m.f.'s, **e'** and **e"**, just as they stand. Such sum is **e'''**, vector **bd,** Fig. 2, obtained in the usual manner by means of the diagonal of the proper paral-

lelogram. By construction, the distance, **bd**, is equal to the distance, **ac**, which closes the triangle formed on **e'** and **e''**. **e''' = bd = ac** might be drawn as a vector from **a** to **c** to express the **result**, i.e., the e.m.f. impressed between **a** and **c** by **e'** and **e''**. **However, this is a vector-circuit diagram wherein every line represents not only an alternating quantity but its conducting circuit as well,—it will not do, therefore, to connect ac with a vector to express the resultant e.m.f. which occurs, not in the circuit ac, but in the circuit abc. It will be legitimate, however, to connect ac with a conducting circuit provided it contains an e.m.f. that is the equal and opposite of that which is applied a and c by the resultant of e' and e'' in abc.** Since such vector-circuit **e''' = ac** is the working equivalent of **e' + e'' = abc** (neglecting internal impedance), it may be joined in multiple with **e' + e''** at **a** and **c** without disturbance in the practical case. It will deliver current to an external loading circuit connected to **ac** just the same as will **e' + e''** in **abc**. In their Fig. 2

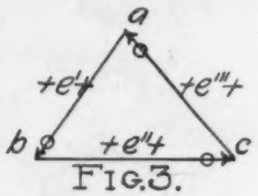


FIG. 3.

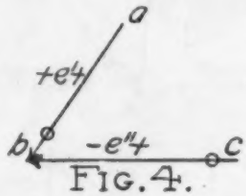


FIG. 4.

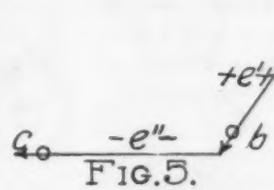


FIG. 5.

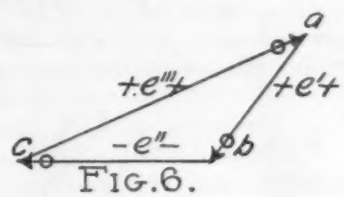


FIG. 6.

relation, **e'** and **e''** are redrawn in Fig. 3 and their anti-resultant **+ e''' +** is drawn as the double-vector closing their triangle.

This process in vector-circuits for obtaining the anti-resultant is called triangulation.[1]

Similar vector-circuits are properly subject to triangulation, while **non-similar** vector-circuits demand operation by parallelogram-diagonals to get their resultant; such diagonals do not register the proper connections for their circuits. The conclusion, therefore, follows that the determination of the resultants of vector-circuits must be accomplished by triangulation as demonstrated above.

Since triangulation may be applied to communities of similar vector-circuits only, communities of non-similar vector-circuits can be operated upon by triangulation only after they have been re-expressed in their equivalent communities of vector-circuits that are similar. Operations upon non-similar vector-circuits to reduce them to similar vector-circuits:

The non-similar vector circuit, **abc**, in Fig. 4, is to be transformed to a circuit of equivalent similar double-vectors. Let **+e'+** remain as it is. Reverse the connection of the circuit of **e''** with respect to that of **e'**, at the same time reverse the alternating value of **e''** with respect to its circuit. A double reversal has been made and the working result has not been changed. This has been done in Fig. 5 where triangulation is now practicable and **+e'''+** has been found to be the anti-resultant or equivalent e.m.f.-circuit of the circuit **abc** containing the e.m.f.'s **e'** and **e''**; see Fig. 6.

[1]At the close of this paper a method is given for identifying actual circuits, e.m.f.'s, etc., and their corresponding double vectors, so that the latter may be a guide in making real circuit connections.

It is well to remember that the practical cases designated by the original e.m.f.-circuit **abc** in Fig. 4 and the one in Fig. 5 are actually different, though the duties they will render are identical. The e.m.f.'s **e''**, Fig. 4 and Fig. 5, are opposite and their circuits have been correspondingly reverse-connected. The original is not subject to triangulation and the use of a properly chosen equivalent of similar vector-circuits **is an expedient** that permits triangulation to determine the desired equivalent resultant.

Current Tapped From a Junction of Two Alternating E. M. F.'s Differing in Phase.

A polyphase current circuit and therein two e.m.f.'s **e' and e''**, differing in phase, are designated by means of a pair of corresponding double-vectors, **+e'+** and **+e''+** in Fig. 7.

A conductor **bd** is connected so as to tap current from the junction of the two current sources at **b**, which is, therefore, the graphic origin of the common loading circuits. The loading circuits must be mounted so that their relations to the common tap-conductor **bd** are similar. This is done by branching them from the end of the tap-conductor in a positive or anti-clockwise direction through the proper loading resistance **r'** and **r''** to the other source terminals, **a** and **c**, respectively. The loading resistances

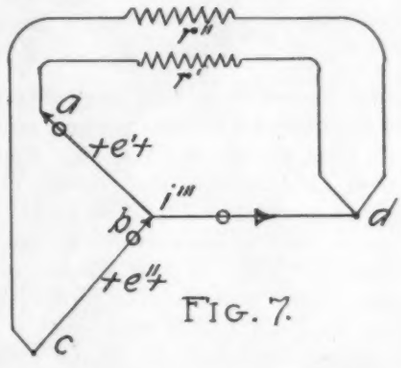


FIG. 7.

are taken non-inductive; the corresponding procedure when loading at a power factor less than unity will be obvious. The currents **i'** and **i''** in the circuits **bdr'ab** and **bdr''cb** are in phase with their corresponding e.m.f.'s **+e'+** and **+e''+**. A study of these circuits reveals the fact that the e.m.f.-circuit **ba** is connected in its loading circuit reversed while **cb** is connected direct. To understand the phase-relation of the currents **i'** and **i''** in the tap-conductor or **bd** which has a similar relation to the loading circuits in which it performs common duty it will be necessary to bring the source e.m.f.-circuits into the same connective relation to their loading circuits, and, therefore, to the tap conductor. The e.m.f.-circuit **cb + e''+** is already

in standard or positive relation to its closed loading circuit. To bring $+e'+$ into a similar relation with its closed loading circuit, it must be completely reversed, an operation, as shown above, that causes no change in the practical result, but which will cause this e.m.f.-circuit to have a direct, in lieu of a reversed, connection in its loading circuit.

This has been done in Fig. 8. All connections are now made similar by operations that do not change the result. The resulting current in the tap-conductor **bd,** or i‴, is therefore, readily obtained, correct in amount and true in phase position, by the ordinary geometric addition of its parts i′ and i″. The current-vector i‴, in Fig. 8 may now be remounted without change in Fig 7, using **b** as its origin to express the total current set up through the tap **bd** and the specified loading circuits by the polyphase e.m.f.'s $+e'+$ and $+e''+$.

Using the same pair of e.m.f.-circuits and with phase-circuit relations varied through the range made possible by reversals of one or both e.m.f.-phases, one or both circuits, or by total reversal of one or both e.m.f.-circuits, the several different double phase sources of

FIG. 8.

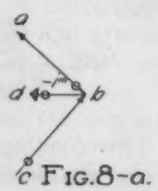


FIG. 8-a.

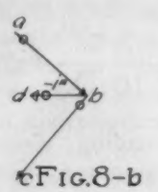


FIG. 8-b.

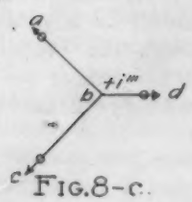


FIG. 8-c.

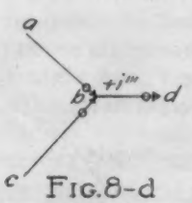


FIG. 8-d.

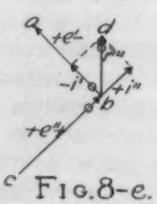


FIG. 8-e.

current to be tapped from the junction point **b** are formed and designated by corresponding vector-circuit diagrams in Figs. 8a, 8b, 8c, and 8d. Applying the above method to determine the current in the tap-conductor, such current is found to be i‴, the same in amount as in the first instance for all cases and the same in phase for Figs. 8c and 8d and of opposite phase for 8a where the circuits were reversed and for 8b where the e.m.f.'s were reversed.

The foregoing combinations did not include those that can be made up so that they must be designated by non-similar vector-circuits. Fig. 8e relates to one of these combinations that has to be designated by non-similar vector-circuits. It is the same as that in Fig 7 except that the terminals of the **ab** em.f.-circuit have been reversed. Going through the method to determine the current tapped through the conductor **bd** and the same corresponding loading circuits continued to **a** and **c,** it is found that the circuits **ab** and **cb** are now both connected direct in their loading circuits, the currents they establish make a direct combination through their common tapping conductor **bd** and must be combined geometrically as they occur to form i⁗, Fig. 8e, which differs from the foregoing resulting currents in both amount and phase.

Practical Examples.

With the foregoing understanding of the principles that govern the use of vector-circuits it is a simple matter to reconcile the polyphase vector diagrams given in Fig. 9, 10, 11, 12 and 13.

In Fig. 9 the topographic points of alternating potential **abc** are the result of a delta connected three-phase source of e.m.f.'s shown by the corresponding delta of vector-circuits. In the cases given in Figs. 9, 10, 11, 12 and 13 **abc** are in each instance identical potential points produced by the same identical e.m.f.'s applied direct in Fig. 9 and in the other cases as resultants quickly found by triangulation. In days past one of the great difficulties in the graphic study of polyphase currents has been to reconcile the fact that the e.m.f.-circuits of Figs. 11 and 13 deliver identical potentials at the terminal points **abc.** In Fig. 14

FIG. 9.

FIG. 10.

FIG. 11.

FIG. 12.

FIG. 13.

FIG. 14.

FIG. 15.

FIG. 16.

vector-circuits designate the delivery of a six-phase alternating potential at the current tapping points **adbecf.** These e.m.f-circuit sources are mesh-connected. In Fig. 15, three three-phase e.m.f.-circuits are star-connected by connecting all three midcircuit points. In Fig. 16, six six-phase e.m.f.-circuits are star connected, these e.m.f.'s have each one-half the values of the three-phase e.m.f.-circuits in Fig. 15. In all three cases, Figs. 14, 15 and 16, the topographic potential points are identical; vector-circuit triangulation in Figs. 15 and 16 shows that the star-connected three and six-phase e.m.f. sources deliver six-phase potentials at **adbecf,** identical with those delivered by the six-phase mesh-connected e.m.f.-circuits in Fig. 14.

To assist the reader in applying triangulation to the double-vectors that designate open delta or star-connected e.m.f.-circuits the details of the process will be repeated for the two cases given in Figs. 11 and 13.

In Fig. 11 it is first desired to find by triangulation the e.m.f.-circuit that is the working equivalent $+e'+$ and $+e''+$ applied in series through **adc.** Taking a positive direction through the closed circuit **adca,** it is found that the circuit **dc** is connected direct and **ad,** reversed. By reversing the vector-circuit $+e'+$ no change in the working result is effected

while its circuit is made to be direct connected. This operation has been performed in Fig. 17. Since both e.m.f.-circuits are now direct connected to the closed circuit **adca,** the e.m.f. may be added in the usual manner. The result of such an addition is the vector **a** directed to **c** and its equal and opposite or working equivalent is **c** directed to **a.** The vector-circuit $+\mathbf{e}''''+$ as drawn in Fig. 17 is, therefore, the working equivalent of the values $+\mathbf{e}'+$ and $+\mathbf{e}''+$ as given in in Fig. 11. In the same manner, in Fig. 11, it is seen that the e.m.f.-circuits **bd** and **da** are direct connected in the closed circuit **abda,** and the equal and opposite e.m.f.-circuit of $+\mathbf{e}'+$ and $+\mathbf{e}'''+$ is $+\mathbf{e}''''$, as given in Fig. 18, which gives the results of both triangulations and which shows that the potentials at **ab** and **c**

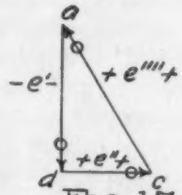


FIG. 17.

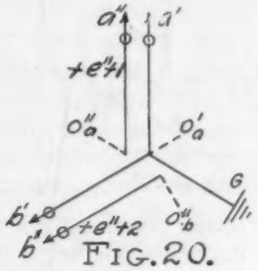


FIG. 20.

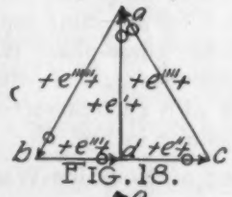


FIG. 18.

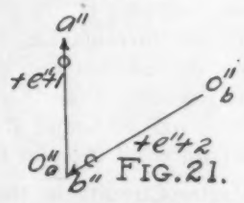


FIG. 21.

FIG. 19.

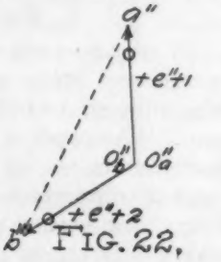


FIG. 22.

are those due to the three-phase e.m.f.'s $\mathbf{e}''''$, $\mathbf{e}''''$ and $\mathbf{e}'''+\mathbf{e}''$ and that they are identical with the three-phase e.m.f. given in Fig. 9. In the Fig. 13 case, $+\mathbf{e}'+$ and $+\mathbf{e}''+$ occupy a relation to the tapping points, **a** and **c,** that is identical with that in Fig. 11; the result is, therefore, the same. Taking a circuit in a positive direction through $-\mathbf{e}'''$ and $+\mathbf{e}'+$ it is found that the circuit of $-\mathbf{e}'''$ is reverse connected. Upon reversing the vector-circuit, i. e., changing $-\mathbf{e}'''$ to $+\mathbf{e}'''+$, it is seen that the anti-resultant or working equivalent vector-circuit for $+\mathbf{e}'+$ and $-\mathbf{e}'''-$ is $+\mathbf{e}''''+$. The completed triangulation is given in Fig. 19.

One more practical example illustrating the use of double-vectors will be a help: It is desired to know how to connect in an emergency the secondaries of two transformers tapping their primary currents to ground from one pair of conductors of a three-phase line operating with a grounded neutral so that the two secondaries will constitute an open-delta three-phase source. In Fig. 20 are given the vector-circuits for the corresponding primary and secondary e.m.f.-circuits.

In Fig. 21, a secondary open-delta connection has been formed by connecting the terminal $\mathbf{o}''_a$ to $\mathbf{b}''$. By triangulation it is seen that a three-phase e.m.f. will be delivered from the current tapping-points $\mathbf{a}''$,$\mathbf{o}''_a\mathbf{b}''$ and $\mathbf{o}''_b$. The phases of the two secondary e.m.f.'s necessarily remain unchanged; to do this and to retain similar vector-circuits so that their working equivalent would close their triangle and thus make a proper three-phase open delta, it was necessary to reverse one pair of terminals $\mathbf{b}''$, $\mathbf{o}''_b$ connecting $\mathbf{o}''_a$ to $\mathbf{b}''$ instead of $\mathbf{o}''_a$ to $\mathbf{o}''_b$ corresponding to the primary connection of $\mathbf{o}'_a$ to $\mathbf{o}'_b$.

If the connections had been made without the reversal of one of the secondaries, the result would be that given in Fig. 22.

Another practical problem is this: Given three sources of e.m.f. differing in phase by one-sixth of a cycle. They are to be connected to form:

1. Delta three-phase source.
2. Y three-phase source.

The vector-circuits for the three original e.m.f.'s and their corresponding circuits are given in Fig. 23.

Without alteration these vector-circuits are thrown into a triangle in Fig. 24. The result is a delta-connected three-phase source of e.m.f. in which the phase interval is one-third instead of one-sixth cycle. To one unaccustomed to the properties of vector-circuits this diagram does not appear correct. It turns up correct, however, if one remembers that the result is not changed when the double-vector $+\mathbf{e}'''+$ is completely reversed in place. This delta-connection of

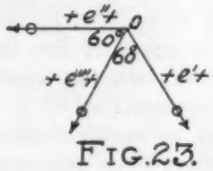


FIG. 23.

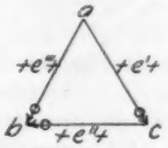


FIG. 24

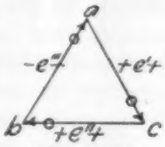


FIG. 25.

Fig. 24 will also stand the test that all proper delta-connected e.m.f.'s must stand, viz:

1. The sum of three e.m.f.'s is zero.
2. By triangulation each e.m.f. is found to be the anti-resultant of the remaining two.

In applying these two checks it is convenient to have $-\mathbf{e}'''-$ substituted, as in Fig. 25, for $+\mathbf{e}'''+$, as in Fig. 24, though it must be remembered that the Fig. 25 connection is not identical with the Fig. 24 connection, and that in any event it is a connection that produces an equivalent result. In making connections nothing can be done to change the actual phase of the e.m.f. $\mathbf{e}'''$; the only change that can be made is to reverse the terminals changing $+\mathbf{e}'''+$ to $+\mathbf{e}'''-$. In the practical case having identified the directions of the e.m.f. vectors and the positive ends of their circuits and having labeled the actual corresponding positive terminals of the real e.m.f.-circuits in the alternator, one may easily read from the vector-circuit triangle, Fig. 24, that one of the three junctions, **e,** forming the delta connection is made by con-

necting the positive end of the e′ circuit to the negative end of the e″ circuit: junction b, the positive ends of the e″ and e‴ circuits: and junction a, by the connection of the negative ends of e‴ and e′.

The three-phase Y-connected sixth cycle set of Fig. 23 is given in Fig. 25a.

From Fig. 25a one reads that the negative end of the e‴: circuit and the positive ends of the e′: and the e″; circuits are connected to neutral. It must be understood that this is the only correct way to designate this connection of the original e.m.f.: circuits as given. To substitute —e′— and —e″— for +e′+ and +e″+ would produce a diagram more like the Y-connection sort that one is accustomed to see, and **while it would be a working equivalent it would not represent the facts and would not tell one properly how to make the practical connections.**

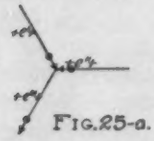


FIG. 25-a.

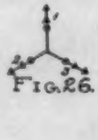


FIG. 26.

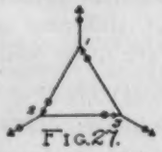


FIG. 27.

FIG. 28.

Proper Designation of Current Tapped from Polyphase Sources.

In the star-connected three-phase case in Fig. 26, there is no doubt about the proper designation of the currents drawn from the loading points 1, 2 and 3. The currents tapped from the junction points in the delta-connected three-phase source are designated as determined above. Owing to the fact that the Y, delta and T-connections of Figs. 26, 27 and 27, produce identical topographic results, it is reasonable, therefore, to expect that the same line currents drawn from either three-phase source should be designated by the same current vectors. The loading currents for the T-connected source in Fig. 28 are drawn the same, therefore, as for the two preceding cases.

To one to whom the properties of vector-circuits are new the phase of i in this case does not look reasonable because it seems to make the +e″+ circuit a negative instead of a positive source of power. With more thought, however, it is seen that +e″+ is reverse-connected in the closed loading circuit extending from terminal No. 2. A reversal of +e″+ does not alter the working result while it causes the resulting —e″— circuit to be direct connected to its closed loading circuit; it is thus seen that this section is a positive source of power. Again, going over the details involved in determining the current at 2, using Fig. 29, will assist further to understand that the i″ power component is in phase with +e″+ and not in phase opposition.

The current drawn through a transmitting conductor from terminal No. 2, has components due to the two sources that meet at this point and deliver therefrom current through their respective loading circuits. To determine these component currents in their proper phase relations, extend, (front view) i. e. in a positive or anti-clockwise direction the two loading circuits from the line conductor connected from terminal 2 through their respective loading resistances $r_{1:2}$ and $r_{2:3}$ to the other phase-terminals 1 and 3. In the $r_{1:2}$ circuit, current is set up by +e′+ and +e″+, both reverse-connected in their closed loading circuit. On totally reversing both, which does not alter the working result, it is seen that the value and phase of their resultant e.m.f. is given by the vector directed from 1 to 2, the corresponding current established by this resultant e.m.f. is $i_{1:2}$ as drawn. Likewise in the $r_{2:3}$ loading circuit both e.m.f.'s-circuits +e″+ and +e‴+ are reverse connected. Upon total reversal of their double-vectors they become direct connected when it is seen that their resultant e.m.f. impressed from 2 upon their loading circuit is given in amount

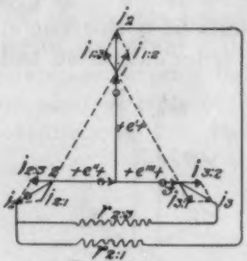


FIG. 29.

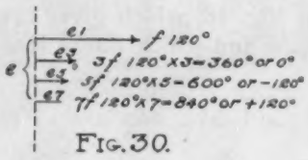


FIG. 30.

and phase positive by a vector directed from 3 to 2 and the corresponding current established is $i_{3:2}$. The total current is the geometric sum of these two component currents **i.e.**, i_2 as drawn. In the same manner the current-vectors at the other three-phase tapping points 1 and 3 may be determined, and when done will be found also to agree with current-vectors set up from the star-connected source in Fig. 26.

Vector-Circuits in the Treatment of Non-Sine-Wave Poly-phase Currents.

Every polygon or mesh-connected poly-phase current source forms a closed conducting circuit within which the sum of all e.m.f.'s at every instant must be zero. When such is not the case, internal "circulating" currents are set up by the residue e.m.f. that results from the imperfect balance of the poly-phase e.m.f.'s. Every non-sine wave is simply an aggregation of waves differing in amounts and frequencies in a manner now well known. The general effect of this will be better understood by looking at a particular case. To do this use a delta-connected non-sine wave three-phase case. The multi-frequencied components of the wave employed are given in Fig. 30.

In Fig. 31, diagram **A** is a vector-circuit delta for the fundamental component e.m.f.; **B** is the corresponding connection for the three-frequency component—e.m.f.—mutilated by being left open at the tapping point **aa** because the phase interval of these e.m.f.'s is zero. **C** is the corresponding connection for the five-frequency component—e.m.f., not mutilated but resulting in a reversal of sequence of e.m.f.-phases, the effect of which, for example, would be to make an effort to reverse the rotation of an induction motor. In **D**, the seven-frequency e.m.f. component produces the same sort of result as the fundamental.

It is apparent that the three effective e.m.f. vectors that express the total e.m.f.'s resulting from a combination of the one, five, seven, eleven, thirteen, etc. frequency e.m.f.'s in the general case will have equal but larger values than the fundamental and that their

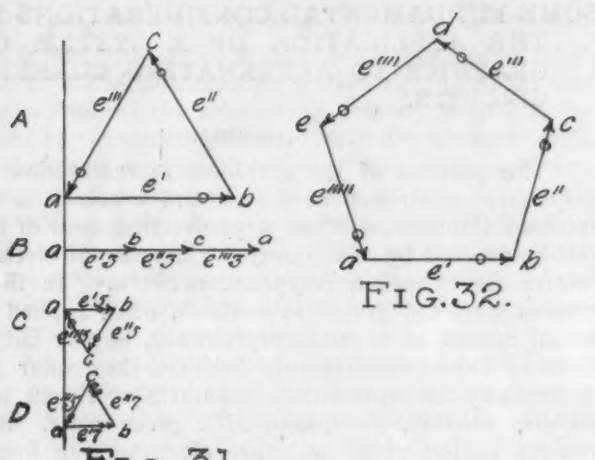


FIG. 31.

FIG. 32.

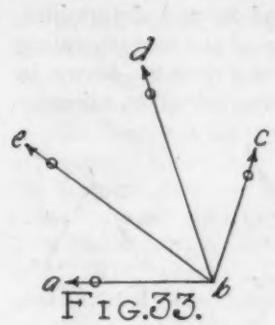


FIG. 33.

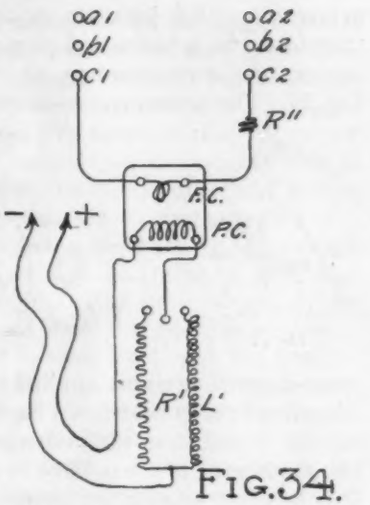


FIG. 34.

phase intervals will be unchanged. It follows that the equivalent sine wave values of total non-sine wave e.m.f.'s and their circuits may be designated by corresponding vector-circuits which may be operated upon in the usual manner to attain desired and correct results so long as those multi-frequencied component e.m.f.'s are absent which do not occur at the same phase interval as the fundamental.

In the foregoing three-phase case, the three, nine, etc. frequency component e.m.f.'s do not have the phase interval of the fundamental and no delta or receiver closed source connection containing those e.m.f's can be correctly represented by vector-circuits because they produce a phase interval for the vectors designating the total effective e.m.f.'s that is different from the phase interval of the fundamental; the source circuit will fail to close by an interval that is equal to the sum of the offending harmonics. As an example, suppose that the three-frequency harmonic is the only offending one, present. It will increase the three total effective e.m.f.'s to the same extent as though quadrature sine-waves having the same frequencies, were being combined. The results when represented by corresponding vector-circuits will show graphically a failure to close the delta, yet the gap thus determined will not be equal to the arithmetic sum of the in-phase three-frequency components nor will it have their phase. In the practical case, however, the circuit-triangle is actually closed and then the offending harmonic e.m.f.'s are consumed by circulating currents internally causing the external disappearance of such offending harmonics. Practicably, with this understanding, vector-circuits may be used to designate all e.m.f.-circuits; and such vector-circuits may be operated upon to give correct results just as though simple sine-waves were employed. An illustration of this is found in the following graphic

Vector-Circuit Proof of the n-1 Wattmeter Power-Measuring Method.

A five-phase closed polygon-connected irregular wave alternating current-source is designated by corresponding double-vectors in Fig. 32. There may be internal circulating currents in this case due to the non-conformity to such a connection of some of the harmonic component e.m.f.'s, yet, it is true, that a fan-connected set of four non-sine-wave e.m.f.'s may be employed to duplicate exactly the topographic potentials at the line tapping points **abcde,** as drawn in Fig. 33, when it becomes evident at once that any power delivered from those points may be measured by taking the sum of the indications of four wattmeters connected in the outgoing conductors at **cde** and **a**; the conductor at **b,** acting as a common return.

Since the validity of the **n-1** wattmeter methods has been established by various independent mathematical treatments, its above application, working backward, constitutes a check upon the conclusion that vector-circuits may with proper recollection of the underlying principles involved, be applied to non-sine as well as sine-wave cases.

Identification of Actual Circuits for the Application of Vector-Circuits.

First, all original e.m.f.'s and their phases, circuits, and their terminals should be identified, vector-circuit fashion, by some such method as that applied in the following particular case:

In Fig. 34, a_1 a_2, b_1 b_2 and c_1 c_2 are the terminals of three current sources. To identify them for vector-circuit designation, connect a non-inductive loading resistance **R″** between the terminals of one of the sources c_1 and c_2 through the field coils of a suitable wattmeter.

The current through the voltage coil must have a dual control; an in-phase control by the usual non-inductive resistance and a quadrature-lagging control by the special form of inductance, such as commonly used in induction meters. By means of a proper switch, either voltage control can be employed at will to read on the wattmeter the voltage components that are in phase and in quadrature with the standard phase-current drawn through **R″** and the wattmeter field coil at **FC.** Label arbitrarily the wattmeter voltage circuit terminals + and —. Using the non-inductive control in the instrument voltage circuit, apply its labeled ends to the source terminals so that the instrument will read positive. That terminal c_1 or c_2, to which the positive end of the pressure circuit has been applied should be labeled **positive.** The reading of the instrument is proportional to the in-phase

pressure applied between c_1 and c_2 and determines, therefore, the amount and phase of the corresponding vector; the corresponding vector-circuit is drawn in Fig. 35. The instrument voltage, circuit-ends, using in-

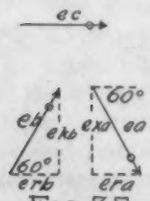


FIG. 35.

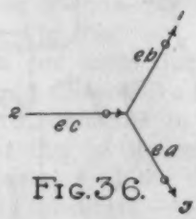


FIG. 36.

FIG. 37.

phase control, are now applied to b_1 and b_2 so that the instrument reads positive. The terminal b_1 or b_2 receiving the + end from the instrument is labeled **positive.** The reading e_r, is the postive in-phase component of e_b. The lagging quadrature control is now substituted in the instrument voltage circuit when the instrument reads positive by the amount e_k, the **leading** quadrature component of e_b. Thus the vector-circuit for e_b is located. See Fig. 35. It was found to lead e_a by 60°. In the same manner the a_1 a_2 terminals were identified and e_a was located and found to lag with respect to e_c by 60°. Its corresponding double-vector is drawn in the same figure.

It is now required to determine:

1. How to three-phase: Y-connect these e.m.f.-circuits.

Operating on their unchanged vector-circuits, there are two ways to throw them into the Y-form. One of these is given in Fig. 36.

At first glance this may look like a genuine three-phase Y or star-connected three-phase current source. That such is the case is seen at once, however, when it is remembered that the total reversal of e_c will not change the working result but will give us that which we know to be a real three-phase source. In the practical case we can only reverse the circuit terminals of e_c we cannot reverse the phase of its alternating value; we must let e_c in Fig. 36 stand as it is and as such the connection is **a true Y-three-phase.** To realize it practically, the negative terminals of the circuits a_1 a_2 and b_2 b_1 and the positive of terminal e_1 e_2 must be connected to neutral.

2. How to three-phase: delta-connect these same e.m.f.-circuits.

Again operating on them unchanged, there are two ways in which they can be thrown into a delta-form. One of these is given in Fig. 37, which is recognized as a proper delta-connected three-phase source when e_c is totally reversed. As it is, it accomplishes the same result, and must remain unchanged because in the practical case total reversal cannot be accomplished, the circuit terminals only can be reversed and that would produce a failure to form a three-phase source-circuit. The diagram is, therefore, correct for the formation of a true delta-connected three-phase source and states that the negative terminal of the e_a and the positive of the e_b, the negatives of the e_b and e_c and the positives of the e_c and e_a circuits must be connected to form the three-phase current tapping points 1, 2 and 3.

SOME FUNDAMENTAL CONSIDERATIONS IN THE APPLICATION OF A SYSTEM OF GRAPHICS TO ALTERNATING CURRENT CIRCUITS.[1]

BY W. A. HILLEBRAND.[2]

The purpose of the graphical representation of polyphase electromotive forces and currents is to facilitate the interpretation or predetermination of the result obtained by combining any number of electromotive forces into a polyphase network. In their present state our graphical methods, when applied to actual instead of to imaginary circuits, largely fail in both of these requirements because they offer no opportunity for representing apparatus or circuit terminals, whereas, the phase of a given e.m.f. with respect to the phase of other electromotive forces with which it may be connected, is, to an important degree, dependent upon the order in which its terminals are connected into the circuit.

Before presenting a system which, it is believed, will satisfy these two conditions, some of the difficulties inherent in a scheme that undertakes to recognize the circuit terminals as well as their electromotive forces, will be dwelt upon.

The first of these is a satisfactory definition of the term "phase difference" or "phase relation," as applied to actual, physical circuits.

Definition of Phase Relation.

The phase difference between two e.m.f.'s is the time interval, expressed as a fraction of a cycle or in degrees, between the instants when each would begin to send current through its own circuit from one specified terminal to another. Accepting this definition, it is seen that the phase relation of one e.m.f. with respect to another is dependent upon the arbitrary choice of terminals and of a direction of reference from one terminal to another. Accordingly, each circuit will be assumed to have a positive and a negative terminal, arbitrarily chosen, and the direction of reference will be from the negative to the positive terminal.

In accordance with these conventions the phase difference between two e.m.f.'s may be defined as the time interval, expressed in degrees, between the instants when each would tend to circulate current from the negative to the positive terminal through its own circuit.

If ab and cd, Fig. 1, are two transformer secondaries with arbitrarily selected + and — terminals as shown, and if, one sixth of a cycle after ab commences to circulate current from a to b via route a T b, cd commences to circulate current from d to c, via dTc, then cd may be said to lag 60° behind ab. If c and d had been marked — and + respectively instead of + and —, then e.m.f. cd would lead ab by 120° instead of lagging by 60°.

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[1]What follows is intended as a discussion of Professor Ryan's paper on the "Graphic Treatment of Polyphase Current Circuits." It was prepared at his suggestion in the hope that an explanation of the difficulties encountered therein would help others similarly troubled, to an understanding of the fundamental principles underlying his conventional treatment. For the sake of clearness it was considered best not to pad the treatment itself with too much explanatory matter.

[2]Professor of Electrical Engineering Oregon Agricultural College.

Symbols.

Since phase relation has been defined with reference to a direction through the circuit, the vector line that represents the alternating quantity must also indicate the circuit terminals. Thus, a chain of such vectors will represent not only the magnitude and phase of the alternating quantities, but the circuit connections as well. The circuit terminals may be indicated by placing a small circle near that end of the vector which represents the positive terminal of the circuit. The other end of the vector line is understood to be the negative terminal.

Accordingly, the e.m.f. and circuit ab of Fig. 1 may be represented as in Fig. 2 or as in Fig. 3, since there is no reason initially for associating the positive or arrowhead end of the vector with the positive terminal of the circuit.

Since cd has been assumed to lag behind ab by 60°, it may be represented as in Figs. 4 and 5, accord-

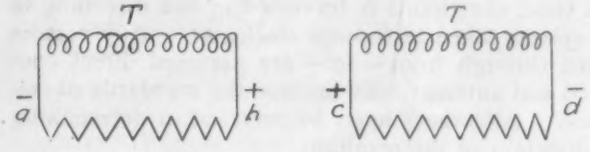

FIG. 1.

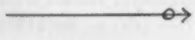

FIG. 2.

FIG. 3.

4.

FIG. 5.

ing to the direction assigned to ab. For the same reason there is a choice, in each case, between two ways of writing the vector.

Suppose now that b and d are connected together and a and c joined to a loading circuit as in Fig. 6. One sixth cycle, or 60° after ab commences to circulate around in the direction abdcyx, cd commences to do the same thing. We have across xy the resultant of two e.m.f.'s 60° apart. Their sum, written in the conventional vector fashion, wherein the vectors represent only the alternating quantities, is xy, Fig. 7.

Employing the double vectors of Figs. 2, 3, 4 and 5, the connection of Fig. 6 may be represented in either of four ways, Fig. 8. Each of these four diagrams correctly represents the facts of Fig. 6, namely, that cd lags 60° behind ab and that the positive terminal of the circuit ab is connected to the negative terminal of cd. Yet in only two of the four cases does the closing side of the triangle correctly represent the resultant of the two electromotive forces.

In Figs. 8, b and c, it will be noted that the vector arrowheads meet. In such a case the closing side of the triangle can not give the resultant of the vector combination. In order that the closing side will also give the resultant, arrow head must connect with arrow foot, which will always be the case, after due account has been taken of circuit connections, if, the vectors are all so chosen that the positive or arrow head end of each vector is associated with the positive terminal of its circuit. The positive ends of the vectors might, with equal justice, be associated with the negative terminals of their circuits, provided the arrangement applies throughout. Thus, in Fig. 8, the e.m.f. circuit cd should be represented as in Fig. a or d.

Reversal of Vector.

The phase interval between the two e.m.f.'s has been defined independently of their connection into a common circuit, yet when so connected, it is necessary to consider their phase interval as largely determined

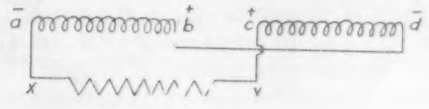

FIG 6

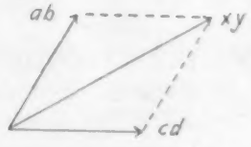

FIG. 7

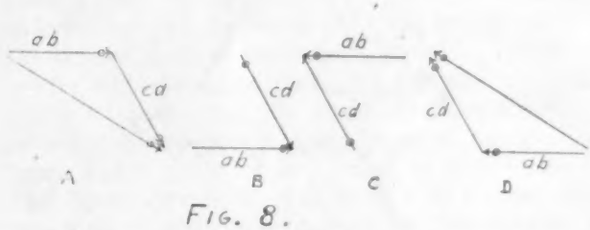

FIG. 8.

by the order of such connection. However, once the phase relation is known for a given set of conditions, it can be readily determined for any other set of conditions, which is the reason for the definition previously given.

Let b and c be connected as in Fig. 9 and let the direction of reference around the circuit be adcdyx. This direction leads through ab from — to +, in the same order as in Figs. 1 and 6, but leads through cd in the opposite direction. This means that the phase of ab is unchanged, but that of cd is reversed, because the direction of reference through cd is opposite to what it was formerly. This is in accord with the physical facts, for cd now commences to circulate current in the direction abcdyx 120° before ab commences to do the same thing. That is, cd now leads ab in its

effort to circulate current through a common circuit. Vectorially, the condition is represented in Fig. 10.

Using the vector relation between ab and cd as originally assumed, the connection is represented in Fig. 11, where the direction of the resultant is obtained as in Fig. 10, by reversing cd.

The question then arises, how to tell when to reverse a vector in order to obtain the correct phase position of the resultant.

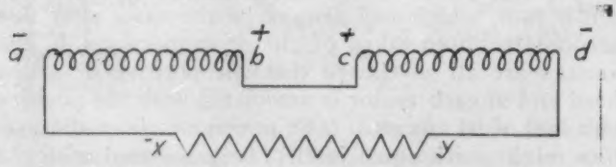

FIG. 9.

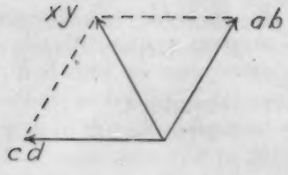

FIG. 10.

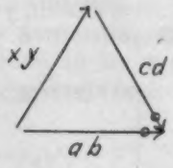

FIG. 11.

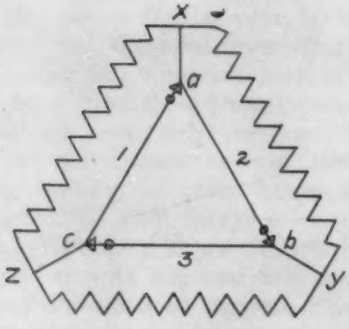

FIG. 12.

Phase relation has been defined on the basis of an effort to circulate current from a negative to a positive terminal. If a series of e.m.f.'s have alternately plus and minus terminals connected, that is, if the succession of terminals in going around the circuit is $-+-+$ etc., then the order in which each e.m.f. tends to circulate current in given direction through their common circuit is the same as the order in which each would circulate current through a separate loading circuit of its own. That is, the phase position of each e.m.f. as originally determined is, in effect, unchanged by its connection into this circuit.

This is the case in Figs. 6, 8a and 8d.

If, however, one circuit should have been so connected that two minus and two plus terminals come together, then the order in which it tends to circulate current through the common circuit is different from the order determined by its separate loading circuit. The effect of reversing the connection has been equivalent to reversing the phase of that circuit.

This is the case in Figs. 9 and 11, in which, starting with terminal "a," circuit cd is found to have been reversed. As a matter of fact, the resultant would have been obtained just as readily by reversing ab, the succession of terminals indicating merely that one vector must be reversed to give the true direction of the resultant.

Choice of a Standard Direction Around a Circuit.

In the two previous cases the circuit ab was taken as a standard and any circuit found reverse connected with respect to it was reversed in the vector diagram. An arbitrary assumption of one vector as a standard of reference is necessary in all cases, but procedure is simplified if, instead of picking out a particular vector each time, the circuit is traversed in one direction, in this system taken as counter clockwise. Any vectors passed through from $-$ to $+$ are assumed direct connected and automatically become the standards of reference. All others must be reversed in determining the direction of the resultant.

Placing of Loading Circuits.

In applying this rule to determine the phase relation of the current drawn from the junction of two circuits, there is one precaution to be borne in mind, which will be illustrated by an example.

Fig. 12 represents three-phase currents, mesh connected, it being desired to determine the phase relation of the current in tap conductor ax. The diagram shows that at a time interval of 120° after current starts to circulate from phase 1 around caxzc, current from phase 2 starts to circulate around byxab, That is, 120° after current in phase 1 starts to flow from a to x, current from phase 2 starts to flow from x to a, or current from phase 2 starts to flow from a to x 60° earlier than current from phase 1. Since phase relation of current or e.m.f. in a given circuit can only be determined on the basis of an assumed direction from one terminal to the other, the two currents in ax are found to be 60° apart.

This could have been determined directly by mounting the loading circuits as in Fig. 13.

Now, in traveling around the two circuits caxzc and axyba, each in the positive direction, circuit ax is passed through in the same direction each time. Current ab is now found to be reverse connected. Hence its phase position with respect to current ca in ax is leading by 60°. The current in the tap conductor ax, to a different scale, is shown in Fig. 14.

In determining the phase position of the current in a tap conductor, the loading circuits must be so placed that in traversing each of the circuits furnishing a component of current in a counter clockwise direction, the common or tap circuit is passed through each time in the **same** direction.

It is of interest to note that had the direction of reference been taken from x to a, in Fig. 12, the phase position of current in ax would be that given in a of Fig. 15. Thus the three phase line currents in a

mesh connected system can with equal justice be represented as in either b or c of Fig. 15, inconsistent as these two diagrams may at first appear.

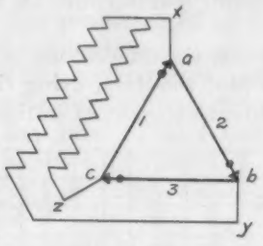

FIG. 13.

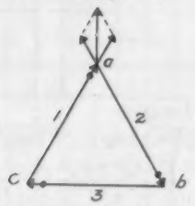

FIG. 14.

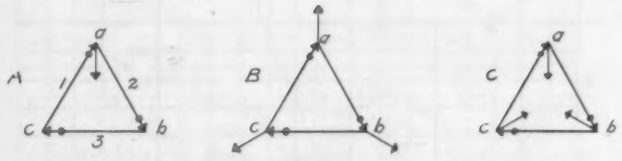

FIG. 15.

In a system wherein every vector represents not only an alternating quantity but its circuit as well, the closing side of any vector polygon must be equivalent to the anti-resultant of the other vectors or else a short circuit will result. This anti-resultant may be represented as ac in either of Figs. 16 or 17, but in a conventional diagram, for the sake of symmetry, the form of Fig. 17 is considered preferable. In some of the previous diagrams, where resultants have been employed, they have been drawn separate from the rest of the diagram, to indicate that actual connection is not intended.

Summary.

The salient points which the foregoing discussion has endeavored to develop are the following:

Phase relation between electromotive forces or currents must be based upon an assumed direction through the circuit under consideration.

It is necessary to have a symbol which will represent both the alternating quantity and its circuit terminals.

It is desirable to so choose the symbols representing a group of alternating quantities that all of the positive circuit terminals are associated with all of the positive vector terminals, or else with all of the negative vector terminals. For instance, it is awkward to work with the vectors of a group of circuits, some of which have the positive ends of the vectors associated with the positive circuit terminals, while others have the positive vector ends associated with the negative circuit terminals.

The phase relation of several interconnected, alternating quantities may be determined with regard to their common circuit by traversing that circuit in a positive or counter-clockwise direction. Each individual circuit which, in this process, is passed through from its negative to its positive terminal, is taken as the standard of reference, and its phase position is

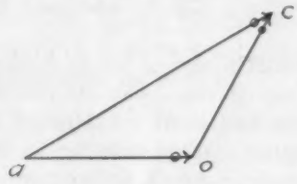

FIG. 16.

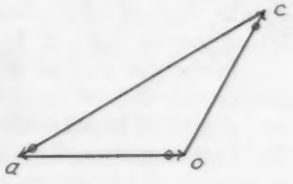

FIG. 17.

assumed to be unchanged. All circuits passed through from positive to negative terminal thereby become reverse connected and their vectors must be reversed in determining the resultant.

In determining the value and phase relation of the current in a tap conductor at the junction of two circuits, it is convenient to so locate the loading circuits that in following around each circuit in a positive direction, the tap conductor is each time traversed in the same direction.

Since each vector represents a live circuit, the closing side of any vector polygon must be equivalent to the anti-resultant of the other circuits.

PROPOSED PANAMA TRIP.

The Board of Directors of the American Institute of Electrical Engineers has under consideration the suggestion of arranging for a trip of inspection to the Panama Canal Zone during the coming winter.

The work on the canal has reached such an advanced stage that by May, 1912, the authorities expect to begin flooding the Gatun Lake and letting water into the various levels of the canal. Therefore, this coming winter will afford the best, and also the last, opportunity of inspecting the work, as it will have approached completion without, however, any part of it being under water or impossible of easy inspection. The Board, therefore, regards this as a most opportune time to make an excursion for this purpose, and we have received unofficial assurances that we will be given every necessary facility and opportunity for a thorough examination of the work.

CANAL WORK IN AUGUST.

The grand total of Canal excavation to September 1 was 148,192,759 cubic yards, leaving to be excavated 47,130,620 cubic yards, or less than one-fourth of the entire amount for the completed canal.

The total excavation in the Central Division for the month of August, was 1,464,294 cubic yards, of which 1,442,402 cubic yards were taken from the Culebra section. This is the greatest amount of material ever removed from the Culebra section in any month of the rainy season since the commencement of the work by the United States.

HOW TO MAKE UP EMPIRICAL FORMULAS.[1]

BY ROBERT SIBLEY.

Two classes of formulas are met with in the practice of engineering—rational and empirical. The so-called rational formulas are those which can be deduced from known physical laws, while those classified under the heading of empirical, as a rule, have little or no theoretical basis back of them, but by mere "cut and try" methods are found to express with a certain degree of exactness the results obtained by actual test or design.

In the study of higher mathematics, we find many interesting deductions. One of the most interesting and practical results which has been established in this higher realm of reasoning is that relating to the expansion of any given equation into a definite series of ascending powers of the variable or unknown quantity. Thus it is shown that for certain definite conditions any variable quantity can be expanded in a series of the form

$$y = A + Bx + Cx^2 + Dx^3 + \ldots\ldots\ldots$$

Nature, in her evident endeavor to simplify her laws, seems to operate largely in the first and second powers of the variable, though occasionally it is necessary to take into account even higher powers. In a large number of cases the results of a test, or the unknown law which it is desired to express in algebraic form, approximates very closely a straight line, which is represented algebraically by the equation

$$y = A + Bx$$

Again many laws in steam engineering seem to obey the exponential law which, algebraically expressed, is of the form

$$y = Ax^B$$

and by taking logarithms of both sides of the equation, this becomes

$$\log y = \log A + B \log x$$

By comparing this with the equation above, it is seen to resemble $y = A + Bx$ in general form, the only difference being that the logarithm of the number appears instead of the number itself, and when it is remembered that actual numbers are found by taking the logarithms of experimental data, the relationship is still closer. Hence if we can find a method of picking out proper constants of A and B in the first equation, a similar process will suffice for the latter, and we shall at once be enabled to form our empirical equation. The rules we shall give, however, are perfectly general and can be easily extended to any power of the variable in terms of which we desire to express our law.

The question now arises as to how we proceed to form an empirical equation, first as to the general expression of the equation, and secondly as to how the constants are actually computed. A concrete example will best suffice to illustrate both points. In the calibration of an anemometer for the measuring of chimney gases, the following data were amassed.

It was desired to get an algebraic expression which would accurately represent this experimental data. In a word, it was desired to form an equation so that by simply substituting in this algebraic expression the number of revolutions the anemometer turned, the velocity of the outgoing gases could be at once computed.

The first thing that should be done in any problem of this nature is to plot the data, using the horizontal line for the independent variable, or in this case for the

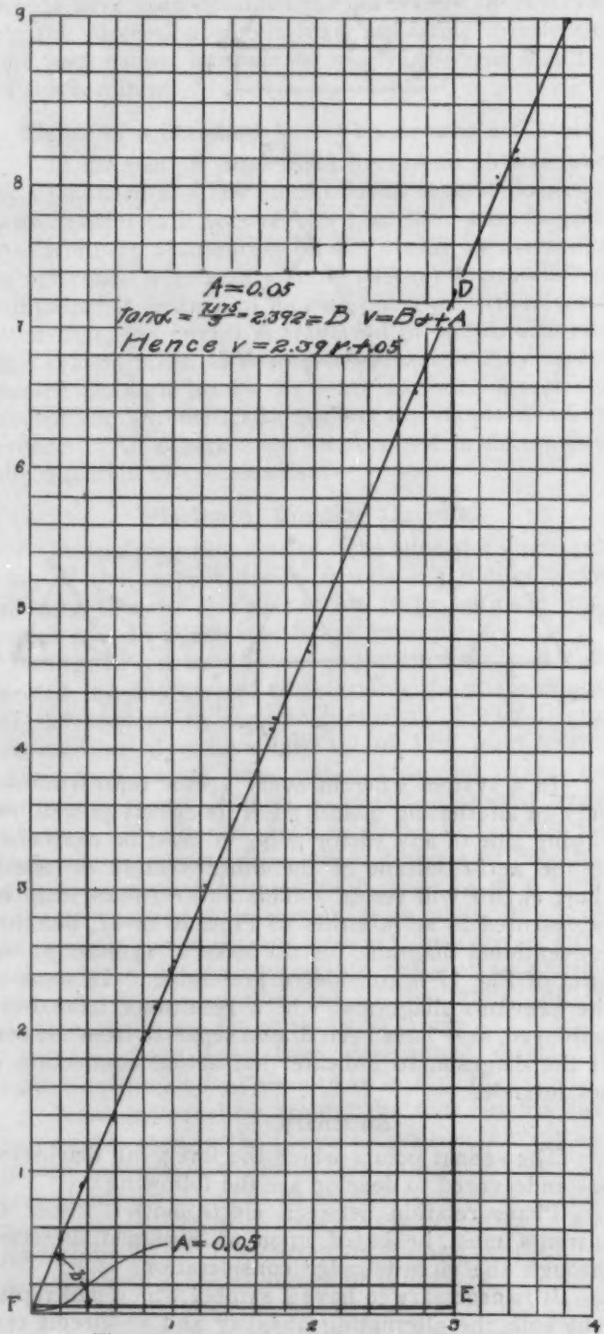

Fig. 25. Straight Line Empirical Formula.

revolutions of the anemometer, and the vertical line for the dependent variable, or for velocity in this example. Fig. 25 shows the resulting curve. At a glance we note that evidently our law is a straight line. Hence we assume

$$v = A + Br$$

In this v is the velocity in feet per sec., r is the number of revolutions per sec., and A and B are con-

[1]To be placed as an appendix in the compilation of the series of lectures appearing in the columns of this Journal as A Primer of Applied Thermodynamics.

stants. Looking for a moment at the diagram we can at once guess with some approximation to the truth, the values of A and B to use in our equation. It is seen, however, that the personal equation enters largely into this process, and as many different equations will be used as there are people guessing. To proceed with this method, however, I measure the distance along the vertical axis from the origin to the crossing of any line. This I find to be 0.05. From elementary analytic geometry, I know then that A has a value of 0.05 in my assumed equation. Again, the constant B is the slope of my line, which I measure by taking any point D on the straight line assumed and scale off the distance DE and FE, which I find to be 7.175 and 3, respectively, or

$$B = \frac{DE}{FE} = \frac{7.175}{3} = 2.392$$

Hence the equation of my curve is in this case,

$$v = A + B\,r = 0.05 + 2.39\,r$$

In order to arrive at the proper values of the constants with mathematical exactness, however, I must form so-called normal equations involving A and B. It is evident more than twenty different values can be gotten. As a matter of fact, the probability is that none of them will be absolutely correct. The rule set forth will, however, pick according to the scientific methods of least squares, the most probable value for the equation we have determined upon. It makes no difference whether there are two constants to be determined or many more, the rule is the same.

No.	Vel. ft. per sec.	Rev. per sec.	Rough Empirical Equations	Formula Normal Equation for A.			Normal Equation for B.		
	v	r	n a b	an	a^2	ab	bn	ba	b^2
1.	1.994	0.819	1.994 = A + 0.819B	1.994	1	0.819	1.634	0.819	0.672
2.	2.162	0.892	2.162 = A + 0.892B	2.162	1	0.892	1.929	0.892	0.796
3.	1.398	0.571	1.398 = A + 0.571B	1.398	1	0.571	0.797	0.571	0.326
4.	0.868	0.357	0.868 = A + 0.357B	0.868	1	0.357	0.317	0.357	0.127
5.	0.899	0.357	0.899 = A + 0.357B	0.899	1	0.357	0.321	0.357	0.128
6.	0.511	0.202	0.511 = A + 0.202B	0.511	1	0.202	0.100	0.202	0.041
7	0.622	0.211	0.622 = A + 0.211B	0.622	1	0.211	0.130	0.211	0.045
8	1.955	0.800	1.955 = A + 0.800B	1.955	1	0.800	1.564	0.800	0.640
9	3.043	1.367	3.043 = A + 1.367B	3.043	1	1.367	3.855	1.367	1.803
10	4.730	1.961	4.730 = A + 1.961B	4.730	1	1.961	9.230	1.961	3.844
11	6.506	2.702	6.506 = A + 2.702B	6.506	1	2.702	17,580	2.702	7.300
12	3.525	1.472	3.525 = A + 1.472B	3.525	1	1.472	5.186	1.472	2.165
13	7.999	3.332	7.999 = A + 3.332B	7.999	1	3.332	26.670	3.332	11.110
14	8.304	3.447	8.304 = A + 3.447B	8.304	1	3.447	28.280	3.447	11.880
15.	8.104	3.332	8.104 = A + 3.332B	8.104	1	3.332	27.000	3.332	11.110
16.	8.196	3.447	8.196 = A + 3.447B	8.196	1	3.447	28.270	3.447	11.880
17.	9.190	3.834	9.190 = A + 3.834B	9.190	1	3.834	35.240	3.834	14.710
18	9.178	3.834	9.178 = A + 3.834B	9.178	1	3.834	35.200	3.834	14.710
19	4.264	1.786	4.264 = A + 1.786B	4.264	1	1.786	7.615	1.786	3.186
20	4.270	1.786	4.270 = A + 1.786B	4.270	1	1.786	7.624	1.786	3.186
21	3.602	1.493	3.602 = A + 1.493B	3.602	1	1.493	5.375	1.493	2.226
22	4.176	1.725	4.176 = A + 1.725B	4.176	1	1.725	7.199	1.725	2.975
23	2.496	1.038	2.496 = A + 1.038B	2.496	1	1.038	2.573	1.038	1.083
24	2.412	1.000	2.412 = A + 1.000B	2.412	1	1.000	2.412	1.000	1.000
25	1.534	0.617	1.534 = A + 0.617B	1.534	1	0.617	0.940	0.617	0.381
26	1.532	0.637	1.532 = A + 0.637B	1.532	1	0.637	1.009	0.637	0.406
27	1.331	0.535	1.331 = A + 0.637B	1.331	1	0.535	0.714	0.556	0.289
28	1.167	0.466	1.167 = A + 0.466B	1.167	1	0.466	0.544	0.466	0.217
Total				186.918	28	43.914	259.536	43.914	108.018

In the table above appear twenty-eight equations with two unknown constants, A and B. In order to determine the most probable values of A and B, we must, as stated above, form socalled normal equations. Multiply the components of each equation by the coefficient of A in that equation, thus forming twenty-eight new equations. Add the corresponding coefficients in each equation, and thus form the socalled normal equation involving A, which is seen along the line heated, total, in the above table. Similarly, form the socalled normal equation involving B by multiplying the components of each equation by the coefficient of B in that equation, and by footing up the coefficients as shown in the above total, referred to. Thus we have now two equations, involving two unknown quantities, as follows:

$$28\,A + 43.914\,B = 105{,}918$$
$$43.914\,A + 108.015\,B = 259.336$$

Solving for A and B according to usual methods of algebra for two simultaneous equations, we have

$$A = \frac{28 \times 259.336 - 43.914 \times 105.918}{28 \times 108.015 - 43.914 \times 43.914} = 2.377$$

$$B = \frac{105.918 \times 108.015 - 259.336 \times 43.914}{28 \times 108.015 - 43.914 \times 43.914} = 0.0477$$

Hence in this case we are enabled to arrive at the most accurate equation for the calibration of our meter. The equation is the following:

$$v = 0.048 + 2.38\,r$$

By substituting in the above equation, the experimental data, it will be found to represent accurately each set of values determined in the test. It is very often the case that the first power of the variable is not accurate for the proper representation of our test. The second power will nearly always be found to represent almost all lines that are fairly even and which do not turn back on themselves when plotted—in other words such lines as are wholly convex or concave. If still closer results are desired, the third power will still more nearly correctly represent the function. In any event the method outlined in forming the normal equations is perfectly general, and will pick the most probable values for the constants involved, whether or not the equation assumed is on the whole a representative expression for the data found by experiment. The only way one can be sure that the equation does finally represent the data is to actually substitute the values in the equation so found, and it will be seen at once to what degree of accuracy the equation may be depended upon.

The logarithmic law above alluded to is assumed many times in the practice of engineering.

Simple examples involving the logarithmic law may be found in the following thermotwisters. The student is advised to try their solution. If this logarithmic law is once mastered, an excellent weapon in analysis is added to an engineer's equipment.

Thermotwisters.

1. Darcy and Bazin experimenting on the flow of water compiled the following experimental data:

No. of exp.	1	2	3	4	5
Mean velocity (v)	1.73	1.98	2.17	2.33	2.46
Hydraulic radius (r)	11.4	14.4	17.0	19.2	21.2

Assuming that the velocity of water in channels is of the form of $v = m r^n$, show that $v = 0.446\ r^{.65}$ is an empirical formula for compiling the mean velocity.

2. In a steam engine it is found that after cut-off takes place the pressures and volumes during expansion of the steam have the following values:

60	lb. absolute press.	corresponds	to	7.107	cu.	ft.
50	" "	"	"	8.429	"	"
40	" "	"	"	10.39	"	"

Assuming the steam expands according to the law $p\ v^n = K$, where n and K are constants, determine their value.

SOLUTION OF THERMOTWISTERS—EIGHTH LECTURE.

1. Water is to be raised from 60° F. to 200° F. in a feed-water heater, the weight of water being 10,000 lb. per hour. Heat is supplied by steam at atmospheric pressure, 0.95 dry. Find the weight of steam condensed (a) in an open heater, (b) in a closed heater. Find the surface necessary in the latter.

(a) From feed-water formula in lecture, we find

$$W(x_0 L_0 + h_0 - h_2) = w(h_1 - h)$$

where $x_0 = .95$, $L_0 = 970.4$ $h_0 = 180$, $h_2 = 168$, $w = 10{,}000$, $h_1 = 168$, $h = 28$.

$$\therefore W = \frac{10{,}000\,(168-28)}{0.95 \times 970.4 + 180 - 168} = \frac{1{,}400{,}000}{933.9} = 1500. \quad \text{Ans.}$$

(b) In this case $h_2 = h_0$. Hence substituting

$$W = \frac{10{,}000\,(168-28)}{0.95 \times 970 + 180 - 180} = \frac{1{,}400{,}000}{921.9} = 1520. \quad \text{Ans.}$$

To compute surface necessary in (b)

$$S = \frac{W L_0}{180\,(t_0 - t)} \text{ in which } t_0 = 212 \text{ and } t = \frac{200+60}{2} = 130.$$

$$S = \frac{1{,}400{,}000 \times 970.4}{180\,(212-130)} = 921 \text{ sq. ft.} \quad \text{Ans.}$$

2. Steam 0.96 dry at 130 pounds gauge pressure delivers 3250 pounds of water per hour from an injector at a temperature of 165° F., the inlet temperature of the water being 62° F. The water is measured on the inlet side of the injector. Find the weight of steam used. The velocity of the entering water is 13 ft. per second. That of the discharge is 115 ft. per sec. Find the velocity of the steam leaving the discharge nozzle. How many boiler horsepower are required or represented in the steam necessary for the injector.

Since y = No. of lb. of water per lb. of steam, then x lb. of steam would draw in xy lb. of water, or $xy = 3250$, but

$$y = \frac{x_0 L_0 + h_0 - h}{h_1 - h}$$

From tables for 130 lb. pressure (gauge) $L_0 = 865.3$, $h_0 = 327.1$, $h = 30$, $h_1 = 133$.

Hence substituting

$$\frac{3250}{x} = \frac{0.96 \times 865.3 + 327.1 - 30}{133 - 30} = \frac{1128.1}{103}$$

$$\therefore x = 3250 \times \frac{103}{1128.1} = 2940. \quad \text{Ans.}$$

$$xy = 3250 \quad \therefore y = \frac{3250}{x} = \frac{B250}{294.0} = 10.93$$

$$\text{Since } v_1 + y v = (1+y)V$$

$$\therefore v_1 = (1+y)V - y v = (1+10.93)\ 115 - 10.93 \times 13 = 1514. \quad \text{Ans.}$$

Since injector requires 294.0 lb. of steam per hr., which has been heated from water at 62° F., the energy represented per hr. is

$$294.0\ [0.96 \times 865.3 + 327.1 - 30] = 333600 \text{ B.t.u. per hr.}$$

$$1 \text{ Boiler H.P.} = 970.4 \times 34.5 \text{ B.t.u. per hr.}$$

$$\therefore \text{H.P.} = \frac{333600}{970.4 \times 34.5} = 9.92. \quad \text{Ans.}$$

LETTER TO THE EDITOR.[1]

Editor Journal of Electricity, Power and Gas:

San Francisco, October 31, 1911.

In compliance with your request I am handing you herewith a discussion in the form of a letter to the Editor, which I have entitled, "Public Work and Engineering," and which practically covers the conversation we had the other day. I wish to impress upon you that these remarks are made "sine ira et studio," and are based on a number of occurrences I have witnessed during my eleven years' practice in this country. The remarks do not refer to any individual case, nor do they refer to any individuals connected with any specific public enterprise, and the incentive for expressing my opinion as I did during our recent conversation lies principally in the fact that I have been familiar for twenty years with the ways of carrying out public work in the old country and by force must make comparisons.

The term "public work" in this discussion is applied to any construction work which is undertaken by federal, state or municipal authority and to be paid for out of public funds.

At the present time an extraordinary amount of such work is under way in the United States, partly due to the steadily increasing tendency toward public ownership, partly due to the fact that certain work of engineering requires so large an amount of money and an organization so vast that it could hardly ever be undertaken by private capital. As belonging in the latter class I will mention the Panama Canal and the development of the United States Reclamation Service, harbor work and river regulation, state highways, and, for municipal work, water supply, sewerage, municipal street railways and light and power plants.

If anyone or any corporation can afford to avail itself of the best engineering talent it should be the government, no difference whether federal, state or municipal, and as a rule it can do so at considerably less expense than private parties or corporations, because engineers, quite frequently, have the excusable weakness to place prestige above remuneration. Without any question, public work should be of the very best and no expense spared to obtain the most satisfactory results money can procure and the state of the art can produce. This lies in the nature of conditions: public work is executed without consideration for dividends, nor is there any time limit set within which the work must have paid for itself. In other words, while individuals rarely go into an enterprise where more than ten to twenty years are required to make the originally invested capital available again for investment, and corporations borrow money for from twenty to forty years on an average, the government may easily finance a public enterprise on the basis of redeeming its bonds in not less than ninety-nine years, thus reducing the amount to be set aside annually as sinking fund for such redemption.

[1][The editor is pleased to publish the above discussion which has been furnished him in the shape it is printed, and wishes to state that this journal is not responsible for any of the opinions uttered by the writer of the letter; but an invitation to the use of our columns is always extended for discussion of fruitful topics.]

As a matter of fact, we find to-day public work designed and constructed on a much higher plane of perfection than any private work, but we do not always find the best engineering talent connected with such work. This may be partly due to the fact that the best talent is not always available at a moment's notice, or that it cannot always be readily found· many engineers of great ability are entirely too unassuming to put themselves in the limelight of publicity—or the red tape and favoritism often connected with public work frightens the talent away, sometimes even after it had been discovered and won for the work.

Enginering talent may display itself in three distinct branches and very rarely may an individual be found that is efficient in all of them. These are:

1. Planning work, which requires theoretical and practical knowledge of the particular branch of engineering specialized in and intuition for quickly finding the best solution of a new problem;

2. Designing work, which requires theoretical and practical knowledge, but as a rule to a much higher degree than in the first case, which results in a subdivision into specialists to a greater extent than for planning work.

3. Execution of work, which requires much less theoretical knowledge, but more practical experience than either of the two first named branches, and besides that a high degree of experience in handling matter and men, tact and diplomacy, and last, but not least, the ability to select lieutenants successfully to create and maintain an organization and to get away from detail work.

When we come to scan over the engineering personnel connected with public work we generally find the first branch fairly well represented, the second one very poorly, if at all, and the third one better than perhaps anywhere else.

Why is it so? The question may be answered by the well-known law of inertia applied to human nature. Scanning over advertisements relating to help wanted and situations open, the word "permanent position" or even "life position" is paramount. Even the younger and youngest members of the profession seem to be anxious to get located where they can stay and "grow with the business." This is a mistaken idea which has frequently stifled the most promising talent. While it may be true that the rolling stone gathers no moss, it is not less true that the stone that once got stuck in a rut of a scarcely traveled country road may provide itself of a most venerable covering of verdure as time goes on, but had it kept on rolling it might have seen many sights and gathered many experiences, and no bumps received in that experience are too hard if only our stone does not take such jumps that it will break into worthless fragments.

Great armies in time of war depend more on their reserves than on their yeomanry, especially in case of reverses, both for rank and file and for officers. Where are the reserve officers in the government engineering army to be found when big work is calling them?

HEINRICH HOMBERGER,
Mem. Am. Soc. Civil Engs.
Mitglied Verein Deutscher Ingenieure.

COMPLIMENTARY LUNCH TO PHILIP S. DODD.

About forty prominent electrical men of San Francisco met at luncheon at the Palace Hotel on November 7 as the guests of the General Electric Co. and of the Journal of Electricity, Power & Gas. The meeting was called primarily to give a hearing to Philip S. Dodd, secretary of the Commercial Section of the National Electric Light Association.

Mr. Dodd spoke on the subject of cooperation among electrical men. After a brief introduction on the advantages of getting together, he cited a number of specific instances showing the benefits of this spirit at Cleveland, Ohio, laying particular emphasis of the results of a mutual working understanding between the central station and the contractor.

The speaker called special attention to the splendid results that have followed the publication of a peoples' electrical page in the leading newspapers of Cleveland and fourteen other cities. He showed how the same scheme could be applied at Seattle, San Francisco and Los Angeles and urged the formation of a permanent electrical club to father the idea.

In this connection he spoke of the work of the Sons of Jove and various electrical lunch clubs in generating a spirit of harmony and indicated the tremendous possibilities of even more aggressive methods.

Mr. Dodd was followed by Mr. Victor Gates of Pittsburg, who told how the electrical men of his city finally got together to boost the game to their mutual benefit. Mr. C. C. Hillis, of the Electric Appliance Co., also told of the work of the Sons of Jove and urged closer action.

John A. Britton, president of the San Francisco Gas & Electric Co., laid great stress on the necessity for cooperation between the central station and the manufacturer, the jobber and the retailer, showing how an ill-advised electrical installation brings the central station into disrepute through no fault of its own. He illustrated his theme by the immediate results of cooperation between his company and the contractors. In a few well-chosen words Mr. Britton promised to lend his assistance to Mr. Dodd's several suggestions and urged like action on the part of all others present.

Dr. Thomas Addison detailed the work that has been done by the General Electric Co. in educating the public as to the advantages of electricity and gave his strong endorsement to the proposed work of the Commercial Section of the National Electric Light Association.

T. E. Bibbins, who acted as toastmaster, closed the meeting with the suggestion that this be but the first of a long series of regular gatherings of like nature. With the hearty concurrence of all present he named November 28th as the date for the next meeting to which all electrical men are cordially invited. As a committee to arrange for speakers he appointed S. J. Lisberger, H. V. Carter and E. B. Strong. Adjournment was then taken.

WHAT EVERY ENGINEER SHOULD KNOW.

Part I.

Every engineer should know how to write a clear, forceful report; a concise, direct, one-meaning specification; and a simple, un-clouded, effective business letter. If, then, the wrong use of capitals is an actual drawback to the engineer, let us banish this curse from our daily practice.

Scores of letters violating the established rules for the use of capitals come each week into the editorial department of the Journal. Some rules are given below with examples taken from our correspondence, which, we trust, will aid engineers in correcting this defect.

I. The names of the months, the days of the week, and proper names in general should all be capitalized. Remember, however, that spring, summer, midsummer, autumn, fall, winter, and midwinter should not be capitalized; neither should north, south, east, west and their compounds (north-west, etc.), and derivations (northern, etc.), unless they designate divisions of the country.

Wrong: Many engineers travel West in Winter to hibernate in Los Angeles but by February they are so pleased with their surroundings some city in the west usually becomes their permanent abode.

Right: Many engineers travel west in winter to hibernate in Los Angeles, but by February they are so pleased with their surroundings, some city in the West usually becomes their permanent abode.

II. Titles of persons should be capitalized when used in connection with proper names. Titles of governmental officers of high rank should be capitalized, whether or not they are used with proper names. All other titles not used with proper names should not be capitalized.

Wrong: William Howard Taft was master of ceremonies during October at the ground-breaking exercises for the Panama-Pacific International Exposition to be held in San Francisco in 1915. The Postmaster at San Francisco in mailing the letters containing the joyful news was as busy as the president.

Right: William Howard Taft was master of ceremonies during October at the ground-breaking exercises for the Panama-Pacific International Exposition to be held in San Francisco in 1915. The postmaster at San Francisco in mailing the letters containing the joyful news was as busy as the President.

There seems to be a growing usage however among technical journals to put without capitals titles following the names in personal columns. Thus:

Wrong: James H. Wise, Assistant General Manager of the Pacific Gas and Electric Co. was recently at the Redondo plant of the Pacific Electric Co.

Right: James H. Wise, assistant general manager of the Pacific Gas and Electric Co., was recently at the Redondo plant of the Pacific Electric Co.

III. Capitalize club, company, society, college, high school, railroad, county, river, lake, park, street, or any other common noun, where it is made a component part of a proper name; not otherwise.

Wrong: Many engineers of note recently attended the high jinks of the Bohemian Club. The graduates of many Colleges were there and everyone enjoyed the hospitality of this famous Club.

Right: Many engineers of note recently attended the high jinks of the Bohemian Club. The graduates of many colleges were there, and every one enjoyed the hospitality of this famous club.

IV. Capitalize nouns and adjectives of language or race, such as German, English, Spanish, etc.

Wrong: The heat required to raise one pound of water from 15° F to 16° F is known as one british thermal unit or as is usually technically expressed, 1 b.t.u.

Right: The heat required to raise one pound of water from 15° F. to 16° F. is known as one British thermal unit, or, as is usually technically expressed, 1 B.t.u.

V. Capitalize the first word of a sentence. This rule applies in general to quoted sentences; but not to a quoted sentence from which words are omitted at the beginning, nor to a quoted sentence-element incorporated in an original sentence.

Right: The latent water powers of the Inland Empire have been compared to Shelly's "Arethusa," in which she is described as

" . . . . . ever singing
In murmurs as soft as sleep."

VI. Do not capitalize a clause following a semicolon.

Wrong: Centrifugal pumps have two excellent characteristics; Their first cost is low; they require little skill for maintenance and operation.

Right: Centrifugal pumps have two excellent characteristics; their first cost is low; they require little skill for maintenance and operation.

Better: Centrifugal pumps have two excellent characteristics; namely, low first cost and little skill required in maintenance and operation.

CENTRAL STATION COMMERCIAL PROBLEMS.

BY A. C. McMICKEN.

One of the problems confronting commercial managers in the rapidly growing cities of the Pacific Northwest is the matter of extension of lines. The suburbs of most of our cities are growing rapidly and requests are being made continually for electric service to the more or less isolated and sparsely built districts. It is, of course, desirable to wait until these districts are well built up before making any extensions to serve them, but this is hardly possible of attainment, so persistent are the pleas for service. The problem of taking care of this business has been met in numerous ways. Some companies have resorted to a cheaper line construction than is used in the more thickly settled districts, but this method has proven unwise for the reason that before such lines have passed their useful life the rapid growth of the district has made it necessary to rebuild and reconstruct to a large extent in order to give service. A number of companies require the customer to deposit a sum equal to the cost of constructing such extensions, which sum is credited to his lighting account. The customer must consume sufficient energy in one year or less, to absorb this credit or the balance is forfeited to the company. Other companies require the customer to guarantee an income equivalent to one-half of the cost of the extension the first year, after which period the regular minimum is effective. This is done both by taking a cash deposit equivalent to one-half the cost of the extension and crediting it to the light account and by having the customer sign a contract to pay not less than one-twelfth of this amount each month as a minimum bill. Where it is possible to get several customers on the same extension, the matter is simplified somewhat by pro rating the cost of the extension. A number of other methods are used, accurate data on which was not procurable. A further discussion of this subject at this time will bring out many valuable ideas.

The difficulty of making line extensions pay in new districts where no guarantee other than the regular one dollar minimum is asked, has been more or less successfully met in several ways. The sale of electric irons and cooking devices by systematic house to house canvass being the most successful

means. Small motor installations for pumping water in districts where city service is not available, is also a factor. Numerous electric ranges have been sold in districts where there is no gas service and where long hauls make the price of other fuel high.

The introduction of the electric range presents another problem. Energy at three cents per kilowatt hour is equivalent to one dollar gas or six dollar cord wood, which makes the sale of these ranges comparatively easy. The problem is whether this class of load is desirable, particularly in the outlying residence districts where feeder capacity is none too large and regulating is harder to maintain. It is generally conceded that most of this load is off peak, yet the fact remains that some of it does overlap the peak and whether the cooking rate be three cents or five cents per kilowatt hour, is it profitable business for the central station? It is certainly impractical to connect a sixty ampere range on a long secondary and the expense of extending primaries and providing additional transfomer capacity has to be taken into consideration. The demand for these ranges is steadily increasing and these problems will have to be solved by all of us before very long. At present one of the great drawbacks to the "house electric" is a satisfactory means of heating large quantities of water by electricity at a nominal cost. There are many types of electric water heaters, none of which are without many objectionable features.

A number of the smaller central stations are still wrestling with the gasoline bugaboo. This form of illumination aside from the first cost, is very cheap and in many instances the introduction of high efficiency lamps has failed to meet the gasoline plant either in cost of operation or maintenance. Some central stations have bought up all the gasoline plants and piled them in the junk heap. Others have made free installations of high efficiency lamps and have been able to hold the customer because of the greater safety, convenience, better appearance and lack of heat and odor of the electric installation. A number of gasoline plants still remain, however, and this problem is still before us.

In some cities the gas company is well entrenched by reason of its being established long before the central station and for this reason there are many buildings and houses which have never been wired. The growth of the city away from the old business center and the erection of the modern buildings leaves a class of tenants in the old structures who usually feel that they cannot afford to wire for electricity. The property owner usually does not want to make any improvements until such time as he can remodel or rebuild the whole structure. This puts the matter of wiring up to the central station if it wants this business. In many instances the owner or tenants have been willing to pay for this wiring if allowed to do so in installments paid monthly to the central station.

The growth of the electric power business in the past few years has been tremendous. Probably the most serious problem met by the power engineer in our coast cities and towns is the oil burning isolated manufacturing plant. Fuel oil is now being purchased at from 70 cents to $1.25 per barrel and in years gone by was bought as low as 50 cents per barrel. With this fuel a number of isolated plants are producing power as low as thirty dollars per horsepower year and the majority of plants of fifty horsepower and larger do not exceed forty dollars per horsepower year for ten hour operation per day. To induce such plants to change over to electric drive at rates profitable to the central station requires some ingenuity and very careful study on the part of the power engineer. Waste fuel from saw mills and planing mills is also a serious competitor. It has been proven in a number of instances that the manufacturer is often willing to pay a little more per horsepower year for electricity providing the output of his factory can be increased by the installation of motors and the reduction of friction losses usually accomplishes this point.

The rapid adoption of small high efficiency lamps by meter residence consumers is another source of worry to the commercial manager. They have done much to reduce the income from residence business and many central stations have taken steps to control the sale of high efficiency lamps smaller than forty watts in size. Others have helped out the earnings by pushing the sale of cooking and heating devices and a few have adopted new forms of ligthing rates with the idea in mind that they are selling service rather than a commodity. The high efficiency lamp, generally speaking, has been a boon to the central station, making it possible to secure much business which could not be reached before and educating the public to the use of more light.

In our larger cities the installation of isolated plants in office buildings, hotels, laundries, etc., has to be continually fought against. The high state of perfection attained by the manufacturers of this class of machinery, together with the necessity for steam heat for at least nine months out of each year, gives the isolated plant engineer many excellent talking points. Unless the central station is in a position to sell both steam and electicity the best salesmanship and engineering ability is necessary to secure large loads of this kind. It is often possible for a modern isolated plant installed in a large hotel, for instance, to produce energy for a very small cost per kilowatt hour, due to the large amount of steam and hot water necessary in a building of this class.

This class of competition has in a number of cities driven the rates charged by the central station to a dangerously low figure, as well as causing no little dissatisfaction among customers who were not in a position to demand rates on the competitive basis of this kind. No commercial manager likes to see an isolated plant installed in his city, and the question arises, "Shall we get the business at any price or let the isolated plant go in?"

So multitudinous are central station commercial problems that volumes could be written and still not touch many phases of the subject. In order to bring out more ideas a general discussion of the foregoing at this convention and an opportunity for further problems to be presented will undoubtedly be time well spent.

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Elsewhere in these columns will be found a few examples of correct and incorrect use of capital letters in technical writing.

An Old Fault

Many engineers in their written reports, specifications, or business letters so conceal their true meaning by high-sounding technical expressions, that the readers, upon whom they seek to make an impression, are left wholly in ignorance as to the real meaning of the mental commotion which they have endeavored to decipher.

Again some engineers capitalize words without regard to correct usage among English speaking people evidently thinking this will add emphasis to important points in the discussion. They have an idea that this undue capitalization in words may add capitalization to the project under consideration. Possibly they use capital letters as Dr. Samuel Johnson used ponderous words, thinking that if the pistol misses fire, the butt end may accomplish the purpose. A report or a specification, or a business letter rent with unmeaning capitals, sprinkled in at improper places is as forceful as the continued underlinings in little Mary's first love-letter to her school-boy sweetheart.

In making our written reports to our clients it is well for us to remember that the majority of modern readers, though in a sense the simple folk of yesterday, are no longer of the superstitious, easily convinced, take-it-as-you-say men of yesterday. Each point must be carefully and clearly proved; the specification must be open to but one interpretation; the business letter must be a simple expression of the ideas to be conveyed.

Vector Diagrams

The use of vector diagrams has greatly simplified the solution of the perplexing and complicated problems met with in the study of alternating current circuits. In obtaining the resultant electro-motive force impressed upon a circuit which receives its energy from two separate transformer secondaries, we are compelled to consider certain phase relationships between the two circuits and in doing so we unconsciously assign in our mental vision a definite polarity or direction to the terminals necessary in the connections. A thorough understanding of the papers of Professors Ryan and Hillebrand, found elsewhere in these columns, will greatly simplfy problems of this sort in the future. They add a new written language to alternating current expression. By means of the symbols suggested, no longer is it necessary for us to bear in mind the polarity of connections in forming vector diagrams, for by proper assumptions at the start, the correct relationships are maintained throughout the discussion.

One of the most perplexing factors in the practical demonstration of the use of vector diagrams is this

question of proper terminal connections. We are often able to compute with certainty the resulting electromotive forces and phase relations in the working out of theoretical combinations, but when it comes right down to the actual making of the connections, how frequently we are puzzled as to end to end relations! The new symbolic language actually representing on paper what each one must have formerly carried mentally in the solution of such problems will aid greatly in this practical application in the future.

At best the vector quantity is difficult of grasping even by those who have careful training in similar channels of reasoning. But to the uninitiated, or to the beginner who has had little previous mental exercise, the grasping of the idea of computations involving magnitude and direction is as difficult a mental feat as the physical performance of simultaneously patting the head with one hand and rubbing the stomach with the other.

If we have given that a river launch is capable of moving at the rate of eight miles an hour and a log is floating down with the current which travels four miles an hour, upon asking the average thinker to tell you whether the launch will be bumped harder in traveling up-stream or down-stream by collision with the log, one seldom gets the correct answer; namely, that the shock is the same in either case. In a word, this idea of polarity plays an important role in all engineering problems requiring the solution of factors involving directed magnitudes.

It is to be hoped that the new ideas presented in the papers referred to will be thoroughly mastered by the electrical fraternity and this new weapon of analysis in the future become a part of our symbolic language.

Economic Distribution Control in Los Angeles

Los Angeles presents to the engineering world and to those interested in civic control of public service corporations, an interesting spectacle. A decade ago this municipality awoke to its world-wide commercial possibilities. For years previous, local civic bodies and other organizations interested in the upbuilding of a great southern empire had recognized that a peculiar energy giving indescribable something existed in the lower western latitudes unknown to other parts of our country, which spurs men on to dreams and to deeds no one would dare elsewhere. And so it was that the dawn of the new century found this enterprising municipality, not only annexing a coast harbor sixteen miles away by means of the socalled "shoe-string" addition, but by a united boosting publicity campaign sending word of her greatness and growth to the very innermost recesses of our nation.

What was the result?

Every commercial enterprise was encouraged to enter Los Angeles. Great power companies were induced to spend millions, not only in actual power plant building but in the installation of a carefully designed net-work of distribution throughout the length and breadth of the city. Capital has continued to flow in from all sides, and a system of interurban electric lines has been built which for their size and convenience in service have become the wonder and admiration of all. The rapid growth of this close connection between city and country built up the rural districts on all sides. This rise in population of the surrounding country on the other hand so reflected its strength by causing continued prosperity and growth in the southern metropolis that the municipality awoke a few years later to find not only the domestic water supply absolutely inadequate for their dreams of empire in the distant future, but a shortage almost on the morrow staring them in the face. Situated in the heart of a country that already needs for its daily life every drop of water nature supplied, their only hope lay in the far distant Sierras. The efforts of the experts retained to solve the serious problem confronting the city were finally crowned with success by the city's undertaking the gigantic task of bringing its water supply from the Owens River project some four hundred miles away. It was early recognized that in order to meet the enormous interest charges in the investment necessary for the consummation of the project, every available source of income should be taken advantage of. A very pleasing feature of the Los Angeles aqueduct enterprise is its enormous power possibilities.

The question now arises as to the method to be employed by the municipality in effecting the distribution of this power throughout the city. The power companies operating in Los Angeles have perfected their distribution net-work at an enormous cost. The optimistic boosting spirit of the citizens of Los Angeles has reared this child of their creation after their own ideals. Economic law demands that those having the matter in hand should give the most earnest consideration to the question of the city's either taking over the present distributing systems in their entirety or maintaining a joint operation. For a powerful municipality, which has gained much of its power in the past by the aggressiveness of the capital there invested, to disregard these factors which have lent so much to their upbuilding, might almost be classed as child destruction.

A decade ago the people of Los Angeles by fireworks and much noise were inviting capital to enter their city in the way of investment in public service corporations. But now some advocate disregarding these vested interests in the consideration of the installation of a new distribution system, and, simply because the municipality may have the upper hand, deal a death blow to this gigantic investment which was encouraged on all sides a few years back.

This idea of a popular cry loudly preaching against the sins of monopoly and at the same time because of its present entrenchment advocating the biggest municipal monopoly of all without any regard for the fathering of these investments in the past, is all wrong. It savors too much of papa's lecture to little Johnnie on the evil effects of Sunday fishing, in which papa concludes by saying, "but remember papa likes fish for Sunday dinner."

PERSONALS.

George C. Arrowsmith of the Pacific Power & Light Company, was a recent Seattle visitor.

Thomas Mirk, of the firm of Hunt, Mirk & Co., is at San Diego in connection with engineering contracts.

William S. Graham, manager of the Snow Mountain Water & Power Company of Ukiah, is at San Francisco.

John S. Eastwood, the designer of the multiple arch dam, has opened offices in the Hearst Building, San Francisco.

S. K. Colby, manager of the electric railway department of Pierson Roeding & Co., is visiting the Pacific Northwest.

A. G. Jones, sales engineer with the General Electric Company's San Francisco office, is visiting the Eastern factories.

S. J. Van Ornum, city engineer of Pasadena, was an interested attendant at the recent Municipalities League Convention at Santa Barbara.

Joseph Hanna, manager of the Niles Car Company, with headquarters at Cleveland, Ohio, who is touring the Coast, has arrived at San Francisco from Portland.

A. Emory Wishon, manager of the southern division of the San Joaquin Light & Power Corporation, with headquarters at Bakersfield, has been visiting San Francisco.

J. W. Perry, general manager of the H. W. Johns-Manville Company, arrived from the East during the past week and spent several days in visiting the San Francisco branch.

O. B. Wilcox, of the New York and London firm of Bonbright & Co., who were the underwriters of the Great Western Power Company's first isue of bonds, is at San Francisco.

Samuel O. Dunn, editor of the Railway Age-Gazette, is a recent Portland visitor. Mr. Dunn expresses himself as greatly interested and surprised at the railroad activity in the Northwest.

E. J. Nally, vice-president and general manager of the Postal Telegraph Cable Company, who is making an inspection of the Pacific Coast offices, spent the past week at San Francisco.

George Cole, of the John R. Cole Company, has returned to San Francisco after spending several weeks at the various eastern factories represented on the Pacific Coast by his firm.

Samuel H. Powers and H. R. Tobey, who are connected with the firm of N. W. Halsey & Co. of New York and San Francisco, are at San Francisco conferring with Cyrus Pierce, the Pacific Coast manager.

William E. Coats, president of the Coats & Burchard Company of Chicago, public appraisers and engineers, was recently in Portland looking over this field with a view to establishing a branch office.

H. A. Russell, local sales manager for the General Electric Company, recently returned to his office at San Francisco, after visiting the company's Eastern factories and attending electrical conventions.

Dr. Thomas Addison, Pacific Coast manager of the General Electric Company, has returned to his headquarters at San Francisco after spending two weeks in visiting the Eastern factories and New York City.

Fred L. Webster, Pacific Coast manager for the Allis-Chalmers Company, has returned to his headquarters at San Francisco after a brief stay at the Seattle office, where business is excellent in the electrical lines.

H. C. Goldrick, Pacific Coast manager of the Kellogg Switchboard & Supply Company, of Chicago, has returned to his San Francisco office after a tour of northern cities, including Portland, Tacoma and Seattle.

W. B. Cline, president of the Los Angeles Gas & Electric Corporation, is now in the East on a pleasure trip. Mr. Cline expects to be gone several weeks and visit all the principal cities throughout the East and South.

F. L. Johnston, city engineer of Santa Barbara, has been appointed by the engineering section of the Municipalities League to keep tab on the progress of road expenditure and improvement work in the State during the coming year.

C. H. Stockweather, formerly an engineer for the General Electric Company, has been secured by the forest service to do some expert work in connection with the telephone systems used by the service. He is now at Missoula, Mont.

Leo. D. Haas, formerly with the California Electrical Construction Company, and now doing extension work at Martinez under the commercial department of the Great Western Power Company, visited San Francisco last Sunday.

C. F. Stamps of the Los Angeles Gas Appliance Company has returned from a trip in the East, taking in Chicago, and returning via Denver, where he attended the Gas Association meeting. He left Los Angeles again this week for Pittsburg.

A. M. Hunt has given up all engineering work at his San Francisco offices and left for a six months' European trip this week. Mr. Hunt has long contemplated this action on account of his health, and has discontinued all his consulting work.

C. E. Grunsky, the well known hydraulic expert, suggested some interesting ideas at the recent Santa Barbara Municipalities League Convention on taxation of unimproved property to meet its proportionate share of fixed charges in municipal ownership installations.

V. F. Gates of the Safety Armorito Conduit Company has spent the past week on the Pacific Coast, after attending the the Jovian convention at Denver. He was entertained at San Francisco by the electrical men and left for Los Angeles on November 7th, where he will spend several days.

T. G. Bradley, the power-house superintendent of the Siskiyou Electric Power & Light Company, has been visiting the steam and hydroelectric plants of the electric companies which transmit current to San Francisco Bay district. He inspected the Pacific Gas and Electric Company's plant at Electra during the past week.

OBITUARY.

On October 30th Mr. J. J. Ferrier's many friends and associates were shocked by learning of his death by accident. His death occurred on the afternoon of Sunday, October 29th, at his home in Fruitvale, California, the immediate cause being overexertion in physical culture exercises which he had been in the habit of taking daily. The shock to his family and friends was intensified by its unexpectedness, and the seeming irony of the tragedy, for none was more vital, hopeful and full of promise than he.

Mr. Ferrier was born in Sussex County, England, in 1883; came to America in 1903. His first work was with the Mergenthaler Linotype Company of New York; in 1905 he joined the electrification department of the New York Central and Hudson River Railroad and rose from a subordinate position to that of chief draftsman in the steam engineering branch of this work. In April, 1907, he came to San Francisco to enter the electrical engineer's office, Southern Pacific Company, taking a prominent position in the steam and mechanical engineering branches of the Oakland, Alameda and Berkeley electrification. Subsequently he was promoted to the position of office engineer and in this capacity handled a large number of details in connection with the foregoing installation. He was exceedingly able, conscientious and thorough, and

therefore a very valuable assistant in this organization. Besides being a member of the Masonic Order, Foresters and Eastern Star, he was also an Associate Member of the American Society of Civil Engineers and the American Society of Mechanical Engineers.

LOS ANGELES NEWS LETTER.

The Automobile Emergency Company have placed their contract with the Western Electric Company for 3,000 telephones and are rapidly making their installations along the county roads and throughout the city.

The Board of Public Utilities have recommended that the council grant a temporary franchise on San Pedro Street to the Pacific Electric Railway, to operate their suburban cars along that street to relieve Main Street of the congested condition. There is no doubt the council will grant this franchise immediately. The Pacific Electric Railway will complete the Van Nuys extension and cars will be running in about a week from Los Angeles to Van Nuys, via Hollywood.

M. H. French has just secured the contract for about 70 miles of over-head distribution for the Southern Sierras, in and around San Bernardino. Distribution will be made with 33,000 volt primaries. Plans and specifications have been drawn for an electrical railway between Marshfield, Oregon, and North Bend, Oregon. This company is headed by Mr. C. S. Smith of Marshfield. Southern California Edison Company has issued inquiry and specifications for approximately 1,600,000 pounds of 4/O strand, bare copper cable. This material is to be used for transmission lines between Los Angeles and Colton and for Long Beach and Newmark. Bids will be awarded this week.

At a meeting of the exhibitors of the Los Angeles Electrical Exposition it was decided to change the place of location from Fiesta Park to the Shrine Auditorium. This was done after considerable deliberation and principally because of the fact that the government objects to installing their Smithsonian models as well as their other exhibits under a tent. There is no doubt the Shrine Auditorium will lend itself more admirably to electrical decorations, as well as the other decorative features than the tent. Practically 75 per cent of the total space has been signed for and there is no doubt but what the show will be pulled off promptly on schedule. Drawing for the space was postponed from last Thursday to the coming Thursday on account of the rearrangement and we hope to settle that more definitely at that time. The spectacular features of the show are being worked up and there is no doubt but what this will be one of the most entertaining as well as instructive electrical shows that has ever been given. Prizes have been offered to the public schools for drawings and models of electrical apparatus, and Mr. J. H. Francis, superintendent of schools, is lending his assistance in making this feature of the show an attractive one.

The exhibitors who have already arranged for space at the Los Angeles Electrical Exposition are as follows: American Ironing Machine Co., American Multegraph Sales Co., Auto. Emergency Service Co., American Orr Concrete Pole, Bion J. Arnold, Bailey & Brant, Baker Elec. Vehicle Co., Burroughs Adding Machine Co., Baker Chase Elec. Co., Detroit Elec. Co., C. E. Cook Co., California Auto Co., Crocker & Wheeler, Columbus Elec. Vehicle, R. & L. Elec. Vehicle, Dictaphone Company, Southwest Sales Co., U. S. Elec. Machine Co., Duntley Vacuum Cleaner Co., Electric Mechanical Laboratories, Elec. Device Co., Elec. World, The Ohio Elec. Vehicle Co., Fairbanks, Morse Co., J. C. Farrar & Co., Federal Tel. Co., General Electric Co., Gans Bros., Gen. Appliance Mfg. Co., Holden Scenic Clock & Advertising Co., The Hughs Elec. Heating Co., Hughson & Merton, Holabird & Reynolds, Home Tel. Co., Hupp Corporation, Journal of Electricity, Power and Gas; Byron Jackson Pump Co., Kellman Elec. Mfg. Co., B. F. Kieruiff Jr. & Co., L. A. Elec Vehicle Co., Luitwieler Pumping Engine Co., L. A. Brass Mfg. Co., L. A. Rubber Co., L. A. Elec. Railway, Paraffine Paint Co., Pac. Elec. Heating Co., W. B. Palmer, Pierson Roeding Co., Elec. Storage Battery Co., Pac. T. & T. Co., Perry Elec. Works, Phoenix Lighting & Fix. Co., McCrum, Howell Elec. Co., Pacific Electric Railway, The Maintenance Co., National Carbon Co., National School of Trades, National Elec. Works, W. G. Rightmire, Henry J. Rohrbach & Son, Southern California Edison Co., Stoltz Electrophone Co., Security Elec. Shop, Standard Oil Co., Standard Elec. Time Co., Southern California Supply Co., Shredded Wheat Co., Tuttle, Stevens Mfg. Co., Tuec Co., Western Elec. Co., Western Union Tel. Co., Woodill Hulse Elec. Co., J. A. Wilfreth, Western Rubber & Supply Co., Los Angeles Examiner, United States Government, Baker & Hamilton, Throop Polytechnic Institute.

ELECTRICAL CONTRACTORS' NOTES.

B. H. Bendheim, manager of the Newberry-Bendheim Electric Company, is making a three months' trip east.

Contracts for electrical work are being let for the German House Club Building on Polk and Turk streets.

H .C. Reed, manager of the electrical department of the Pacific Fire Extinguisher Company, is in Portland on business.

The contractors who obtained invitations to the get-together luncheon at the Palace last Tuesday noon, appreciated the invitations very much and felt a keen regret that more of the contractors were not there.

F. E. Cabot, president of the National Fire Protective Association, in an address before the National Electrical Contractors' Association, made the following statement: "This country wastes two hundred and fifty millions of dollars every year. But only fifty thousand dollars of that amount of fire losses is due to electrical causes." He further states that he does not think that they owe to any source outside of the insurance interests as much as they do to the electrical contractors.

Co-operation between contractors, jobbers, manufacturers and lighting companies has been preached from the rostrum of the California Contractors' Association for the past two years. The National Electrical Contractors sent out Mr. Duffield to tell us the same thing, the National Electric Association sent Mr. Dodd for a similar purpose, and when our own eminent electrical men, such as John A. Britton and Dr. Addison, tell us the same thing, we cannot help saying "I told you so. Let us all help."

TRADE NOTES.

The General Electric Company has sold to the Schwager & Nettleton Mills, Seattle, Wash., one A. T. B. 4, 1250-k.v.a., 1800 r.p.m., 480 v., horizontal, condensing Curtis steam turbine; also, one C. C. 2, 35-kw., 3000 r.p.m., horizontal, non-condensing Curtis steam turbine exciter unit.

The Pelton Water Wheel Company has closed a contract with the Federal Government of Porto Rico for use in what is known as the Carite Water Power Development, a 1000 h.p. Pelton impulse wheel which is to operate under an effective head of 750 feet at 400 r.p.m., complete with a 30-inch steel pipe line; also a 50-h.p. exciter set wheel. The Westinghouse Electric and Manufacturing Company will supply both main and exciter generators, which will be direct connected to the above wheel.

INDUSTRIAL

E. C. & M. AUTOMATIC CONTROLLERS FOR MOTOR-DRIVEN MACHINERY.

The Electric Controller and Manufacturing Company of Cleveland, Ohio, has recently placed on the market a line of automatic controllers designed for the specific purpose of giving the utmost convenience in the control of motor-driven machinery. It has been estimated that the output of many machines can be increased 20 per cent by the central grouping and convenient arrangement of all the operating levers. "Handiness of Control" is recognized as being very important in securing the utmost production from a machine, and the automatic controllers described in this article were designed to provide this "Handiness of Control" for starting, stopping, or reversing the motor and machine.

The controller consists of a small operator's switch, shown in Fig. 1, and an accelerating unit of different forms, one of which is shown in Fig. 2.

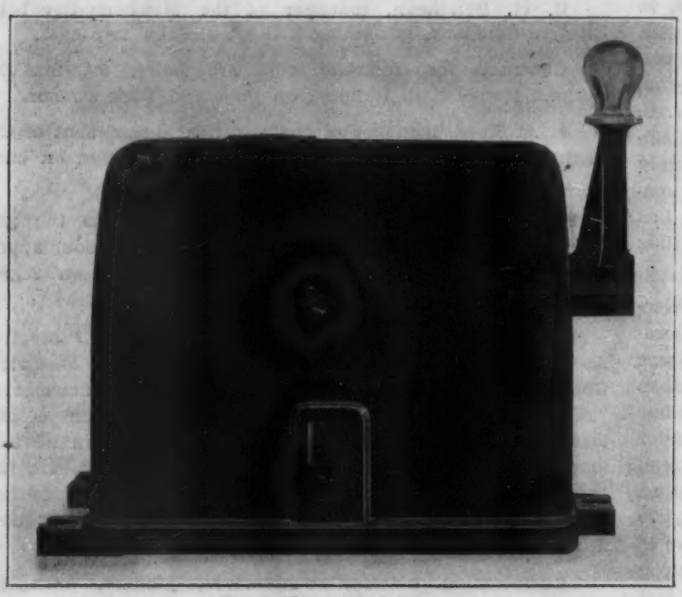

Fig. 1. Operator's Switch.

Fig. 2. Accelerating Unit

The controllers are built in three types to secure: (1st) non-reversing and dynamic braking; (2nd) reversing without dynamic braking; (3rd) reversing and dynamic braking. In each type a variety of four different forms of accelerating units are offered. These accelerating units vary in their design from a simple train of accelerating switches up to a unit having a fused service switch, a train of accelerating switches, and complete circuit-breaker features.

The accelerating unit automatically accelerates or decelerates the motor through the action of series wound accelerating switches which possess the remarkable characteristic of acting not only as switches, but as current limit relays as well. When the current in the winding of one of these switches exceeds a pre-determined value the switch locks open and cannot close until the current is reduced to the proper value.

When the operator's switch is thrown to the running position, current flows through the motor, all of the starting resistance, and the coil of the first series wound accelerating switch. As the motor accelerates the current drops, and when it reaches the correct value the first accelerating switch closes, cutting out a portion of the starting resistance. The succeeding accelerating switches operate similarly, ultimately cutting out all of the starting resistance and putting the motor across the line. By throwing the operator's switch to its original position, the motor is disconnected from the line and consequently stops. Different positions of the handle of the different types of operator's switch provide for drifting, reversing, or rapid stopping by dynamic braking.

Dynamic braking is secured by a change of connections, accomplished by the operator's switch, which first inserts all the starting resistance in series with the armature. The motor is then quickly and evenly brought to rest by automatic dynamic braking, the accelerating switches, in this case, acting as decelerating switches by cutting out, step by step, the resistance as the current, generated by the motor, decreases due to the slowing down of the motor.

The manufacturers claim the following important advantages for this automatic controller:

1st. It limits the acceleration and deceleration current at all times to a safe value.

2nd. It accelerates and decelerates the motor in the minimum, safe amount of time, and automatically varies the time of acceleration and deceleration, depending upon the load which the motor has to start and stop.

3rd. It provided the best conditions for good commutation.

4th. By limiting the current, both in starting and stopping, it limits all mechanical strains on the motor and driven machinery.

5th. It obviates the necessity of mechanical clutches on many motor-driven machine tools.

6th. It adds very materially to the safety of an installation, since in case of accident the motor may be quickly stopped.

7th. It inherently provides no-voltage protection, for if the voltage fails the switches drop open, and upon the return of voltage they automatically close in their regular method and sequence, again accelerating the motor to full speed.

FOURTEENTH ANNUAL CONVENTION AND MUNICIPAL EXHIBIT OF THE LEAGUE OF CALIFORNIA MUNICIPALITIES.

The League of California Municipalities held their fourteenth annual convention at Santa Barbara on October 23 to 28, inclusive. This meeting was by far the most successful, most interesting, and the most enthusiastic of any in the history of the league, and it augurs well for the future of the league. The meetings were very interesting because of the valuable papers presented, the men who represented them, and the men who took part in the discussions. The various municipalities were represented by men of influence who had the power to recommend or condemn matters of procedure in their district, and the exhibitors were represented by their principals—men of wealth, influence and reputation.

The papers presented were as listed in the Journal of October 28th. The exhibitors included: The Barber Asphalt Paving Company, who had a very pretty booth partly of a technical nature and equipped with tables, chairs, writing materials, stenographer and other features of hospitality which were dispensed less publicly. They were represented by Mr. Kent, Mr. Webster, Mr. Alexander, and Mr. Vaile.

The Gorham Engineering and Fire Apparatus Company had a most attractive exhibit, as did all of the following

Exhibit of Standard Oil Company.

firms: Glazed Cement Sewer Pipe Company, Reinforced Concrete Pipe Company, American Glass Sand Company, Pacific Clay Products Publicity Bureau, Pacific Sewer Pipe Company, Braun Knecht-Heimann Company, Union Oil Company of California, The Gamewell Fire Alarm Telegraph Company had a complete fire alarm and police patrol system in operation, Orenstein-Arthur Koppel Company, California Corrugated Culvert Company, The Austin-Western Company, Ltd., A. L. Young Machinery Company, Neptune Meter Company, Dahlstrom Metallic Door Company, J. E. Ward & Co. had a complete Ward Atomizer in operation, West Disinfecting Company, Inc., of New York, Pacific Corrugated Pipe Company, Ransome-Crummey Company, Federal Construction Company, City Street Improvement Company, A. Carlisle & Co., The Destructor Company.

Warren Brothers Company, who had one of the prettiest booths in the place, the main feature of which was a long row of comfortable chairs and the continual dispensing of hospitality by their representatives, Mr. Reese and the Warren Brothers themselves, who came from New York and Seattle, respectively, in order to attend this convention.

The Standard Oil Company had one of the most interesting exhibits in the place, a photograph of which is shown. A complete oil derrick with pumps and wells in full operation were exhibited exactly as they are used in the field. The Standard Oil Company represented their road oils and paving materials in an attractive manner, and took the occasion to present to the public their new catalog and recently issued technical pamphlets on the subject of paving and road oil. They were represented by J. K. Firth, E. N. Percy and C. R. Mallory.

NEW CATALOGUES.

The General Electric Company has just issued a folder—No. B-3147—describing its electric glue pots.

The October number of Common Sense, published by the Electric Controller & Manufacturing Co., of Cleveland, Ohio, is a spicy and interesting issue.

The General Electric Company has recently issued Bulletin No. 4894, which is devoted to cylinder controllers for railway service. This bulletin supersedes the company's previous bulletin on this subject.

The Archbold-Brady Co., engineers and contractors, of New York, have just issued an attractive booklet on steel transmission structures and catenary bridges. The booklet is handsomely illustrated with views of designs constructed and installed by the authors.

Bulletin No. 4886, just issued by the General Electric Company, should be of considerable interest to coal mine operators. There are 59 pages of text and illustrations devoted to the advantages of electric power in operating one mine or a group of mines, and the apparatus used in connection with the operation.

The General Electric Company describes in Bulletin No. 4885, just issued, a new meter designed for accurately measuring the power used by relatively small consumers. The meter is designed for 5 and 10 ampere circuits of 100-120 volts, two-wire, 200-240 volts, two and three-wire, and for 40, 50, 60, 125 and 133 cycle circuits.

Recognizing the need for a standard machine for keeping the commutators of railway motors grooved, the General Electric Company had designed two types of a machine for this purpose and describes both in Bulletin No. 4889, recently issued. One machine is portable and the other stationary, and both require very little space for operation.

To familiarize the public with the Curtis steam turbine generators, the General Electric Company has recently issued Bulletin No. 4883 which is devoted to the general principles of the turbine and the construction of both the turbine and the generator. The bulletin contains illustrations of turbine and generator parts, as well as complete representative installations.

The General Electric Company has issued an attractive publication composed principally of illustrations of the electrical equipment of various railways throughout the country. These illustrations comprise interiors of the power stations, both main and sub-stations, and the rolling stock of various railways. Included among these illustrations are two portable sub-stations. The number of the bulletin is 4891.

Catalogue No. 53 of the Fostoria Glass Specialty Co., Fostoria, Ohio, entitled "Iris Illuminating Glassware," lists, describes and illustrates over 300 different styles of shades and reflectors in colored and iridescent patterns for gas and electric lamps. It conforms in size of page and general conception to the same company's 100-page catalogue No. 52 on cut and etched ware, with the additional feature that each of the ten distinct motifs employed in the decorating of the "Iris" ware is realistically illustrated by a three-color cut.

Bulletin 107, just issued by the Wheeler Condenser & Engineering Co., of Carteret, N. J., is devoted to a discussion of high vacuum jet condensers. The Wheeler rectangular jet condenser, to which a large part of the bulletin is devoted, is constructed on the counter current principle, the arrangement of water trays, baffles, air outlet, exhaust steam inlet, etc., being such that the enormous volume of low pressure steam exhausted from a turbine is efficiently handled with the minimum consumption of water, and the minimum consumption of power on the part of the tail pump.

NEWS NOTES

INCORPORATION.

SACRAMENTO, CAL.—Articles of incorporation for the Sierra Electric Power Company have been filed with Secretary of State Frank Jordan. The company is capitalized at $3,000,000, of which $1000 has been subscribed by the incorporators, Charles Gross, J. E. Howes, E. A. Herman, H. G. Breed and M. S. Hamilton, all of Oakland.

OLYMPIA, WASH.—Articles of incorporation were filed at Olympia last week for a projected railroad from Portland via Vancouver to North Yakima and Ellensburg. Lawrence Harmon, a Chicago attorney, is at the head of the company, which is capitalized for $5,000,000. The other incorporators are C. C. Craig of Portland, W. P. Connaway, cashier of the Vancouver National Bank, and Elmer E. Waite of Vancouver.

SACRAMENTO, CAL.—The Sacramento Water Company, a corporation formed for the purpose of furnishing the city with a supply of mountain water brought from Salmon Falls, near Folsom, has filed articles of incorporation, giving its capital stock at $1,000,000, of which $1000 is actually subscribed. Behind the company are Francis V. Keesling, Ernest L. Brune and J. W. Cook of San Francisco; Otto Grau of Markleeville, and U. R. Grant of Alameda. Keesling is also the promoter of the projected Sacramento-Folsom electric line, which is to traverse the holdings of the Natomas Consolidated. The Natomas Consolidated controls the watershed from which the new water company seeks its supply and it is assumed that the Natomas people are back of both projects. Keesling has secured 2000 inches of water, or 30,000,000 gallons a day, at Salmon Falls, 12 miles above Folsom. His company proposes to build a storage reservoir of 50 million gallons capacity at the end of the Natoma ditch also a regulating reservoir of twelve million gallons capacity. The water will be offered wholesale to Sacramento and if a contract is closed will be piped to the city limits.

FINANCIAL.

SAN FRANCISCO, CAL.—At a special meeting of the stockholders of the Great Western Power Company Thursday afternoon the capitalization was increased from $25,000,000 to $27,500,000 in order to complete the financing of the deal by which the company recently took over the City Electric Company. This was done by the passage of a resolution by the directors of the California Electric Generating Company, a subsidiary concern, to guarantee the payment of the interest upon $1,700,000 face value of the first mortgage 5 per cent bonds of the City Electric Company. By an amendment of the articles of incorporation of the California company the dividends on the preferred stock of the company were made comulative after January 1, 1912.

SAN FRANCISCO, CAL.—The United Railroads has issued a report of the earnings of the corporation for August and the first eight months of the calendar year. The report shows a gain in gross receipts and number of paying passengers carried, as compared with the same periods of last year. No mention is made of operating expenses in the report, or of net earnings and surplus. In August the company earned gross $673,743, an increase of $33,940 over the same month of 1910, when gross receipts were $639,803. During the month 13,474,860 passengers were carried. This is an increase of 778,800 over August of last year. For first eight months of this year 102,787,800 passengers were hauled, as against 100,265,980 for same period of 1910. This represents the large gain of 2,521,820 people carried on the cars of the local street railway combine. The gross returns for this period amounted to $5,130,390 vs. $5,013,299 for same months of last year. This means a gain in gross revenue of $126,091.

SAN FRANCISCO, CAL.—The Sierra & San Francisco Power Company which has quietly been making progress, and is said to have spent a million dollars recently in equipping steam plants in San Francisco, has now made known its readiness to enter into competition for lighting contracts in all the Bay cities. The steam plant at North Beach is said to have a capacity of 25,000 h.p., while the auxiliary plant in Bryant street turns out 3000 h.p. The hydroelectric plant on the Stanislaus River has a capacity of 48,000 h.p., and the plant at Sonora a capacity of 2500 h.p. The company is carrying on an active campaign for contracts at Modesto, Stockton and Tracy, and has recently invaded Berkeley and Oakland. The United Railroads of San Francisco takes 25,000 h.p. under a contract. Both companies are subsidiary to the United Railways Investment Company.

TRANSMISSION.

RINGOLD, WASH.—The Pacific Power & Light Company has consummated a contract with the land owners or Ringold bar for furnishing electric power for irrigation and domestic purposes. A high power line will shortly be constructed.

VALLEJO, CAL.—It has been announced on Mare Island that the work of laying the concrete foundation for the new power plant machinery will be commenced within two weeks. It is estimated that an expenditure of at least $13,000 will be necessary for the work.

TACOMA, WASH.—Chief Engineer Gronen of the Nisqually Power Plant submitted to the Commissioners figures relative to the construction of an electric tramway at the power plant at La Grande. The construction contemplates an expenditure of $18,000.

PORT TOWNSEND, WASH.—An ordinance granting to the Olympic Power Company, a corporation, the right to erect poles, string wires and maintain a transmission line for transmitting electricity from its power plant in Clallam County to the City of Port Townsend, has been passed by the City Council.

SEATTLE, WASH.—City Engineer Thomson, in reporting upon five proposed power projects for this municipality, reported favorably on two, one of them being the Lake Cushman site and the other the P. H. Hebb White river site. The former site would develop power at $93 per h. p., and the latter $89 per h. p.

LOS ANGELES, CAL.—T. C. Dobbins of Gramercy place has received the contract for labor for constructing the Sierra Power Company's overhead power system from San Bernardino to Bishop, Inyo County, at $250,000. It calls for the raising of 240 miles of steel towers 80 feet high, and placing of six alluminum steel cord cables, work to be completed within six months.

WILLOWS, CAL.—The Sacramento Valley Power Company announces that it has bought the Peoples Power Company and is coming into Glenn County as opposition to the Northern California Company, by January 1st. Six solicitors are out here making contracts for power at a rate lower than that charged by the Northern company. A war is looked for in Glenn County between the rival companies.

PASCO, WASH.—James H. Moore of Portland, of the Pacific Power & Light Company, is here, preparatory to instituting preliminary work on the construction of new power and switching stations for that company. The first unit is to aggregate $80,000 and further units are to be added from time to time, and which within a few years will ultimately represent an expenditure of $500,000. The new structures will be the center of high tension wires to surrounding points.

MODESTO, CAL.—The Western States Gas & Electric Company will immediately build a power line from Stockton to Modesto and become an active competitor of the Sierra and San Francisco Power Company for business in Modesto and Stanislaus County towns. This move is believed to be the result of the recent invasion of Stockton by the Sierra and San Francisco Company. The western representative, D. V. O'Callaghan, stated that rates will be cut, and a rate war is promised. The Sierra company recently absorbed the local interests of the Lagrange Power Company and has had the field to itself.

WALLACE, IDAHO.—The Long Valley Light & Power Company has been incorporated by Walter C. Clark, president, who is also chief electrician of the Bunker Hill & Sullivan Mining & Concentrating Company, and is capitalized at $100,000. The company will supply power and water systems to the following towns: Rosebury, Crawford, Van Wyck, McCall, Lardo and Thunder City. The Van Wyck Falls, near Crawford, on the north fork of the Payette, will be developed and will generate 4363 h.p. in low water. The improvements involved are the installation of a 500 h.p. wheel and a 2300 volt generator in a power house. The company's plan for water systems consist of separate wells and tanks for each town and automatically arranged electric pumps.

ILLUMINATION.

CORVALLIS, ORE.—Colonel McGoldrick of San Francisco has applied for a gas franchise here.

SULTAN, WASH.—No bids were received for the construction of an electric lighting plant here.

POMONA, CAL.—The property owners on South Thomas street, from First to Fifth streets are planning for the installation of street lights, similar to those on Broadway, Los Angeles.

GLENDALE, CAL.—The Board of Trustees has passed a resolution declaring its intention to order the installation of the necessary appliances for lighting certain streets with electricity.

SALEM, ORE.—J. L. Day, in charge of the cluster light installations of the Portland Railway, Light & Power Company, is in this city signing up contracts for the installation of cluster light standards.

BLAINE, WASH.—J. E. Morrison, manager of the Nooksack Valley Traction Company, appeared before the council recently asking for a new franchise granting the company running rights over certain streets within the city limits.

EUGENE, ORE.—That the city intends to install a system of gas cluster lights on the business streets has been announced by Mayor F. J. Berger. Work is to be attended to as soon as the money from the sale of the $25,000 electric lighting bonds is available.

CENTRALIA, WASH.—Machinery for the new power plant constructed by the Centralia Light & Traction Company has arrived and will be installed in the next 30 days. Power for the new plant will be furnished by the Eastern Railway & Lumber Company.

TRANSPORTATION.

STOCKTON, CAL.—The survey for the route of the Central California Traction Company's line at Compton to Lockford, has been completed.

BAKERSFIELD, CAL.—A letter from the San Joaquin Power & Light Company to City Engineer Greely states that the company is planning to double track its car lines in this city.

KALISPELL, MONT.—The Flathead Interurban Railway has awarded contracts to L. L. Davis and J. A. Roe et al. for the construction of an electric street railway here. Work has practically started.

CASHMERE, WASH.—The Wenatchee Railway & Power Company has been granted a franchise by the local City Council to operate electric cars on Cottage avenue and Division street in this city.

PASADENA, CAL.—A request for a 30-year franchise, instead of one to run for 20 years, in connection with the proposed extension of the Washington street car line, has been made by the Pacific Electric Railroad.

PASADENA, CAL.—It has been reported that the Pacific Electric Railway is prepared to begin work on the proposed extension of the Washington street line as soon as a franchise is granted by the City Council. Cars will probably be running to the city limits by the first of next year.

NEW WESTMINSTER, B. C.—This place will prepare a charter amendment for the city to reserve a sum of not less than $500,000 per annum as a sinking fund to provide for the purchase of the British Columbia electric street railway and equipment at the expiration of its franchise.

OCEAN PARK, CAL.—According to plans which are now in the hands of Vice-President Shoup, a new electric line will be built from South Eighth Street, Santa Monica, following the National Boulevard to its end, and then travel over private right of way, straight across the country to Ocean Park Heights.

EUGENE, ORE.—General Manager L. Welch of the Portland, Eugene & Eastern Railway Company, announces that Messrs. Hall and Anderson of his company are in the East endeavoring to secure sufficient funds for the construction of the P. E. & E. from Monroe to Corvallis. Construction work may start shortly.

FRESNO, CAL.—M. S. Brackett, general manager of the San Joaquin Valley Electric Railway Company, now building from Stockton to Modesto, has been in Fresno for the past two days investigating with the idea of building out to Fresno. In his visit here, Brackett paid particular attention to the country between Fresno and Madera by way of Kerman.

WALNUT CREEK, CAL.—Within two weeks the line of the Oakland & Antioch Railway will be completed to the town of Lafayette, a distance of 16 miles from the new line's terminus at Fortieth street and Shafter avenue, Oakland. The rails have been laid and the trolley wires strung to within one mile of Lafayette. A big gang of laborers is at work on the one-mile stretch and the gap will be completed within two weeks.

STOCKTON, CAL.—Negotiations which may result in the extension of the Stockton Electric Street Car Company's line into Fair Oaks are known to have been under way for some time. Since the completion of the diverting canal, effectually protecting Fair Oaks from winter overflows, property has steadily increased in value on the local market. Real estate men, realizing that Stockton's growth is to extend eastward during the next few years, have been quietly securing options on pieces of property in the Fair Oaks section.

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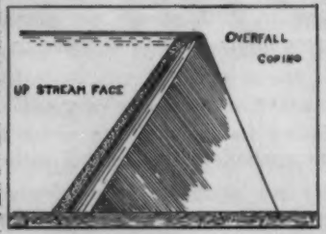

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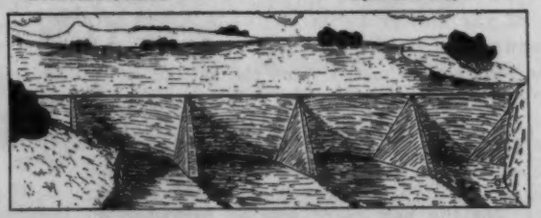
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